3 5 6 2 7 5 L

NEVADA PROVING GROUNDS
OCTOBER-NOVEMBER 1951

Project 7.1

TRANSPORT OF RADIOACTIVE DEBRIS FROM OPERATIONS BUSTER AND JANGLE

ARMED FORCES SPECIAL WEAPONS PROJECT
WASHINGTON, D.C.

50177

...ureau,
W... D.C.

SECRET
Security Information

This document consists of 183 plus 4 pages (counting preliminary pages)

No.[redacted] of 304 copies, Series A

OPERATION BUSTER

PROJECT 7.1

TRANSPORT OF RADIOACTIVE DEBRIS FROM OPERATIONS BUSTER AND JANGLE

by

Philip W. Allen
Project Officer, Headquarters USAF (AFOAT-1)

Lester Machta
Chief, Special Projects Section, U. S. Weather Bureau

Kenneth M. Nagler
Harry L. Hamilton, Jr.
Lester F. Hubert
~~[illegible]~~

15 March 1952

Excluded from automatic downgrading and declassification

Headquarters, United States Air Force (AFOAT-1)

U. S. Department of Commerce, Weather Bureau

SECRET
Security Information

PREFACE

In order to achieve the objectives of this project it is necessary that the final technical report present, as accurately as possible, the movement through the atmosphere of the debris from Operations BUSTER and JANGLE and the distribution of the settled particles at the earth's surface over the United States.

A tremendous number of reports were collected by several agencies, and many of these were in apparent contradiction of each other. Interpretation required a study of the capabilities and handicaps of the various collecting and measuring instruments and of the operating procedures, all of which are published elsewhere and which would be too voluminous to include except in summary form in this report. Further information is available in reports issued by the agencies which developed and/or used the instruments. The interpretation also involved a study of the complex meteorological processes which are continually at work in the atmosphere. However the weather observation network is not dense enough to provide the answers to all questions.

Tabulated raw data are seldom interesting or informative, yet it was felt that the reports should be shown on charts, to convey better than words the problems faced by the analysts, and more importantly, to permit those persons whose instruments were individually affected in some way by the presence of debris to analyse their situations in greater detail.

A minimum of routine meteorological description has been included, since it adds little to the understanding and much to the bulk of the report. Exceptions are made in those cases in which the meteorological factors had peculiar effects on the transport of the debris and which contribute information which may aid in the operation of the Atomic Energy Detection System.

It should be noted by those who have occasion to convey information to the general public that the appendix to this report contains all the information on the distribution of particles at ground level and is classified RESTRICTED when separated from the body of the report.

ACKNOWLEDGEMENTS

This project was in a large part dependent upon other agencies for data which were taken in the routine operations of those agencies or for special purposes in connection with Operations BUSTER and JANGLE. In all cases, the contributions of data were accompanied by valuable assistance and suggestions for which the authors are very grateful.

The program of surface and low altitude air sampling was conducted by personnel of the New York Operations Office of the AEC. Merril Eisenbud, Project Director for that organization kindly contributed their data so that the project would have the advantage of more information and so that correlation of all of the data by one group might produce a single reliable picture. Valuable aid in the interpretation of their data was furnished by Mr. Eisenbud, William Harris, John Harley, and Daniel Lynch of the N.Y.O.O.

The Air Force Special Weapons Command collected the data of the early cloud movement. Lt. Col. Paul H. Fackler, in charge of cloud tracking, and Major Travis M. Scott, as head of the SWC Plotting Room, provided their personal assistance in directing the gathering and interpretation of data.

The cloud height data were obtained through the efforts of the Air Weather Service detachment at the Test Site, Lt. Col. Eugene Karstens in command. The analysis and forecasting section of the detachment, working under Dr. George P. Cressman, from Hq. Air Weather Service, provided the forecast trajectories and some of the meteorological data which were necessary to plan the tracking operation and to interpret the results.

Many of the facilities of the 1009th Special Weapons Squadron and the Air Weather Service were used for the collection of data and its subsequent analysis. Prominent in their contribution are the members of the Air Weather Service detachment, Lt. Col. Louis Bertoni in charge, on duty with the 1009th SWS. The detachment provided the meteorological planning for the interception of the debris at great distances from the Site, and furnished many of the meteorological work charts which were used in the correlation of data. Lt. Col. Ralph Clary of the Technical Analysis Division, 1009th SWS, provided valuable assistance in interpreting radiological data from all sources.

The research assistants of the Special Projects Section of the U.S. Weather Bureau gave invaluable assistance in tabulating data, in performing many of the laborious computations, and in preparing the figures for this report.

CONTENTS

ILLUSTRATIONS

CHAPTER 3 DISTRIBUTION OF RADIOACTIVE DEBRIS

ABSTRACT

The main portions of the Baker and Charlie clouds moved southwestward to the Pacific Ocean and recurved to spread over a large portion of the United States. The Dog and Easy clouds spread southeastward over the Southern states. Both JANGLE clouds moved northeastward and were detected chiefly in the northern part of the country.

The combination of vertical diffusion and fallout with variable low-altitude winds produced broad bands of deposition at the surface. Heaviest surface depositions were associated with precipitation. The evidence suggests that the particles were contained in raindrops. The surface fallout-monitoring program yielded some results which can not be adequately explained and differences were found in the measurements from the various types of sampling devices. (Uncertainty in the significance of tray and gummed paper results restrict the usefulness of the data.) Unusually high activity at Elko resulted from the channeling effect of the terrain on the lower level debris in Nevada.

It has been concluded, relative to the detection of foreign explosions, that under meteorological conditions similar to those during the Dog test, high winds and little shear, it would be possible to fail to intercept an atomic cloud 1500 miles from the source with routine flights every 48 or 24 hours. The shortcomings of meteorological trajectory forecasts, even in regions of good data, were demonstrated in the Underground test and some suggestions are made for improving the liaison between forecasters and operations personnel.

CHAPTER 1

INTRODUCTION

1.1 OBJECTIVE

During Operations BUSTER and JANGLE seven atomic weapons were detonated at the Atomic Energy Commission Nevada Test Site. Project 7.1 was undertaken to determine the distribution of the airborne debris from the tests by meteorological analysis and by a study of data from the detection programs. A knowledge of the distribution of the debris is useful in evaluating hazards to personnel and property, and in planning operations for the detection and location of foreign atomic explosions.

1.1.1 Hazard to Personnel and Property

The airborne particulate debris is transported by the horizontal wind, but also has vertical and horizontal motions due to a complex combination wind shear, eddy winds (too involved to treat other than by turbulence considerations), graviational fallout, and falling precipitation. Past experience indicates that the debris may be carried to very great distances and be deposited on the ground in remote places. It appears that the amount of radioactivity which can be so deposited is far below human tolerance except in the test area and in precipitation within a few hundred miles of the test area. However, the presence of the particles in the air and on the ground may affect sensitive instruments and materials many thousands of miles away.

1.1.2 Detection of Foreign Explosions

The planning of air and ground operations for the detection of debris from foreign atomic tests must be based on reliable information of the characteristics of atomic clouds and the way in which these characteristics vary with weapon, time, distance from the source, and meteorological conditions.

1.2 HISTORICAL BACKGROUND

Although the radioactive particles from the first atomic bomb at Alamogordo were subsequently detected by the photographic industry in paper manufactured more than a thousand miles away from the burst, only mild interest was developed in the atmospheric transport of debris until Operation SANDSTONE, when aircraft fitted with high capacity filters picked up appreciable quantities of fission products halfway around the earth from the test site. The U.S. Weather Bureau made a comparison of these cloud location data with associated wind conditions[1] and found that this dispersion occurred under normal tropical meteorological conditions. Some uncertainty existed, following SANDSTONE, as to the effects of the greater stability and wind shear of middle latitudes on cloud height and distance of transport, but the results of the cloud tracking effort on Operation RANGER[2] showed these clouds to be proportionately high and equally persistent and wide spread. Only one to two days were required for the debris from the Nevada Test Site to be carried to the eastern U.S. where it was found in high concentration at the levels sampled by aircraft and at the ground associated with precipitation. Just two weeks were required for some debris to move completely around the world. RANGER particles were still faintly detectable in the atmosphere at the beginning of the GREENHOUSE tests, two months later. Two clouds from Operation GREENHOUSE were the first to penetrate the stratosphere. The upper portions of these were above the ceilings of tracking aircraft so that the disposition of debris could not be determined except in a very general way.[3] In connection with this operation, the Atomic Energy Commission established a warning service for the manufacturers of photographic equipment, giving the predicted distribution of debris using cloud tracking information provided by Headquarters USAF (AFOAT-1) and meteorological trajectories. This warning service was also set up for Operations BUSTER and JANGLE. It was successful in that the areas covered by debris approximated the predicted areas, but the timing of the arrival of debris from Operation GREENHOUSE was sometimes in serious error due to the paucity of upper air wind data in the Pacific Ocean.

---

[1] U.S. Weather Bureau, Scientific Services Division, Tracking of Airborne Radioactive Material by Meteorological Methods, Report of Operation FITZWILLIAM, Vol. II, Tab A, U. S. Air Force, 1949. (SECRET, RESTRICTED DATA)

[2] U. S. Weather Bureau, Scientific Services Division, Disposition of Atomic Debris Resulting from Operation RANGER, Final U. S. W. B. Report on Operation RANGER, 1 December 1951. (SECRET, RESTRICTED DATA)

[3] U. S. Weather Bureau, Scientific Services Division, report on the meteorological aspects of Operation GREENHOUSE (in preparation). (SECRET, RESTRICTED DATA)

1.3 CHARACTERISTICS OF ATOMIC CLOUDS

For the proper interpretation of the data to be presented, a knowledge of the important characteristics of atomic clouds is necessary. Initially, an atomic cloud consists of a long slender "stem" capped by a broader "mushroom" top. Although appreciable amounts of debris are contained in the stem, the great bulk of the material is in the mushroom cap. The larger particles carried aloft fall out shortly after the explosion. The height to which the cloud rises initially is governed primarily by the character of the burst and the stability of the atmosphere.

The subsequent configuration of the cloud is determined by such factors as the size distribution of the particles and the rate at which they fall out, the nature of the wind field in which the cloud is imbedded, and the manner in which the cloud is diffused.

It is, of course, apparent that all of the particles in the cloud will have some fall velocity. The larger particles will fall to the ground soon after the burst, while the smaller particles will remain airborne for long periods. Knowledge of the size distribution and fall velocities of the particles is so incomplete that only qualitative estimates can be used.

Similarly, the phenomenon of diffusion is difficult to treat in a quantitative manner. It is evident that the ever-present turbulent elements of the atmosphere will tend to diffuse the debris in both vertical and horizontal directions. The extent of the diffusion depends not only on the characteristics of the turbulent eddies of the atmosphere but also on the time and space scale under consideration. As the cloud grows, larger and larger eddies become diffusing elements, so that the rate of growth increases.

The movement of the cloud is governed by the wind field. The trajectory of the primary cloud, that portion of the initial cloud which moves approximately horizontally, unaffected by diffusion or fallout, can be computed by conventional techniques from upper air wind and pressure data. Such meteorological trajectories are naturally subject to error, particularly at levels or regions where there are few upper air observations. In general over the United States these errors average 10 percent to 20 percent of the length of the trajectory.

Horizontal and vertical wind shears coupled with fallout and diffusion are very effective agents in promoting rapid horizontal growth of the cloud. Although primary cloud movement and the effects of shear can be determined quantitatively, the complications introduced by fallout and diffusion make it necessary to use empirical techniques derived from studies of these and other atomic clouds in determining the areas affected by the tests.

CHAPTER 2

EXPERIMENTAL PROCEDURE

2.1 INSTRUMENTATION

The cloud movement and position information presented in this report is the result of meteorological analysis, for which standard weather, wind, and temperature data were used, confirmed and supplemented by cloud detection data. The initial tracking aircraft employed somewhat different techniques in locating the cloud than did the tracking aircraft operating at greater distances from the Test Site. Still other methods were used to obtain measurements of the radioactivity near the ground.

2.1.1 Initial Tracking

Visual contact with the cloud was maintained as long as the debris could be easily seen from airplanes. Accurate visual positioning was possible up to three to six hours after the detonation, depending on the wind shear and the amount of moisture cloud associated with the debris. The eye was unable to outline the diffuse edges of the material, and instruments were required to define the horizontal extent of diffusion.

Measurement of an increase in the small ion concentration by the air conductivity method provided immediate indication of flight through or near the debris. The equipment used is able to detect radioactive particles at a horizontal range of a mile or more, permitting cloud tracking without aircraft contamination. Flight through the debris, even in low concentration, results in deposition of particles in the instrument and on the skin and engines of the aircraft, sometimes raising the background so high that further detection is difficult or impossible. Operations were therefore confined to outlining the edges of the debris by flying just near enough to obtain a low reading above background. The range of the instrument permitted detection of debris at altitudes several thousand feet above and below the aircraft.

The scintillation counter has approximately the same detection range as the air conductivity equipment, but is perhaps too sensitive to changes of concentration for cloud tracking. It provided an interesting and useful check on the other instruments.

Although used primarily for personnel safety, G-M Monitors proved useful as detectors when the aircraft flew too close to or into the debris.

Each cloud tracker airplane was equipped with the standard C-1 foil for the collection of particles, and filters were changed at frequent intervals, but the results were not available immediately and could be used only to confirm existence of debris in the flight path.

2.1.2 Distant Tracking

The tracking airplanes utilized at greater distances from the Test Site were equipped with the air conductivity instrument, a cascade impactor, a G-M tube with a rate meter, and a scintillometer, but all of these were of secondary importance compared to the high-capacity C-1 air filter. The C-1 foil contains two filters, right and left, each having one square foot of exposed area, mounted so that two independent samples can be taken. The airflow through each was about 1000 cubic feet per minute for the filter material used. Collection efficiency was over 90 percent for particles down to sub-micron size.

Normally filters were changed alternately every fifteen minutes, allowing a thirty-minute exposure for each filter. When marked changes in altitude were made, filters were changed more frequently.

Filters were counted at the air base after a minimum waiting period of five hours, which allowed for some decay of natural radioactivity. In the text and figures of this report, all counts pertaining to the long-range detection flights are those obtained at the counting time converted to a common base of counts per minute per half-hour exposure. The conversion of these data to absolute units depends upon the rate of sampling and therefore upon the speed and altitude of the airplane, on the characteristics of the particular bomb, and on the characteristics of the counter. However, an approximation of the disintegrations per minute per cubic meter of air can be obtained by dividing the counts per minute per half-hour exposure by ninety. This conversion factor, in some cases, is in error by a factor of two or three.

2.1.3 Surface Sampling Equipment

For the detection and sampling of debris at the ground three principle items of equipment[4] were used.

A shallow tray having 8.75 square feet of surface was mounted in an exposed position and kept wet with a fraction of an inch of water. After exposure, the water was filtered and the filter was ashed and counted. The process of ashing and counting was also used with a 1.1 square foot gummed paper which was exposed near the ground. A few of these gummed papers were used to produce radioautographs.

The third sampling device, used at only a few stations was the standard air-filtering equipment used by the Health and Safety Division of the Atomic Energy Commission. It has a capacity of 20 cubic feet per minute through a four-inch #41 Whatman disc.

2.2 OPERATIONS

Satisfactory documentation of the history of dispersion of the pillar of dust and bomb debris should have included simultaneous measurements of concentration at a very great number of points throughout the cloud, repeated at frequent intervals during the period of its travel. This being economically impractical, tracking operations were designed around available aircraft and equipment. The work fell naturally into four separate operations: determination of the initial cloud dimensions; determination of the movement of the clouds within a few hundred miles of the Site; determination of the cloud width, and the concentration of debris, primarily over the eastern part of the United States; and determination of the concentration of fallout at the surface over the country. These gave a few essential facts which could be used by the project meteorologists to reconstruct an approximate history of cloud travel.

2.2.1 Measurement of Initial Cloud Dimensions

The Air Weather Service Detachment at the Control Point determined the initial height and width of significant portions of the cloud, using a theodolite. Located at a known distance (10 to 15 miles) from Ground Zero, the instrument was employed to obtain the elevation and azimuth angles to each prominent cloud feature. Triangulation, using appropriate corrections for cloud drift, gave the heights and widths.

---

4 U.S. Atomic Energy Commission, New York Operations Office, Radioactive Debris from Operations BUSTER and JANGLE: Observations Beyond 200 Miles from the Test Site, NYO-1576, 28 January 1952. (SECRET)

2.2.2 Initial Cloud-Tracking Operations

The Air Force Special Weapons Command[5] with the aid of aircraft and crews from the Air Weather Service Weather Reconnaisance Squadrons, followed the debris by airborne instruments out to a distance of 500 miles from the Site or until it was suspected that the radiation was no longer hazardous. Although three aircraft were available for this operation, only one or two were normally used on a single cloud. However, all three were used for the Easy cloud. One plane was in the air near the Site for each detonation and followed the cloud visually. Instrument tracking was accomplished by circling the active region, making periodic turns toward the cloud until instruments indicated above background, then turning away and proceeding to another position on the cloud perimeter where the process was repeated. This succession of point locations was radioed back to the Control Point where they were plotted on a control panel for the information of the Test Director and Project personnel. The second and third planes were sometimes called to relieve or assist the first in the tracking operation. At no time did these aircraft measure the maximum activity of the clouds, although the instruments occasionally deflected full scale. Except in the JANGLE series, the maximum activity, the mushroom, was always several thousand feet above the operating altitude of the aircraft, fifteen to twenty-five thousand feet. Thus, for BUSTER, the tracking aircraft followed not the maximum activity of the cloud, nor the low level debris which offered the greatest hazard to persons on the ground, nor usually even the core of the cloud at any single altitude (due to the great sensitivity of the instruments), but only the edge of the fallout curtain which trailed below the higher portions of the cloud. This obviously complicated the task of fitting the movement into that indicated by meteorological trajectories, but was useful for outlining the broad path of the debris.

The data obtained by the initial cloud-tracking operations are not included in this report but are tabulated in the Technical Air Operations Report, by the Special Weapons Command; however, based on these data maps were made showing the initial movement of each of the clouds and are shown in the appropriate sections of Chapter 3.

2.2.3 Long-Range Cloud-Tracking Operations

The 1009th Special Weapons Squadron, with the aid of additional units from the Air Weather Service Reconnaissance Squadrons, conducted air sampling operations from Robins Air Force Base, Georgia,

---

5 USAF, Special Weapons Command, Technical Air Operations Report for BUSTER-JANGLE. (SECRET, RESTRICTED DATA)

primarily along the 84th meridian. These flights are denoted by code name LARK WILLIAM. The planes were dispatched on the basis meteorological predictions of the cloud trajectory. These planes passes through the cloud as it progressed across the meridian, but again the major portion of the activity was usually above flight altitude, and all flight altitudes were well above the surface. few flights, termed LARK BAKER SPECIAL and LARK CHARLIE SPECIAL, made southward and southwestward from Sacramento, California, to the clouds which moved in that direction.

All data obtained from these long-range detection flights are included in this report. Maps containing the data fr each flight are included in Chapter 3 in the discussion of the appropriate burst.

2.2.4 Surface Sampling Operations

The AEC, New York Operations Office, with the aid o U.S. Weather Bureau, installed fallout trays and gummed papers at stations in the United States for Operation BUSTER, and 10 more f Operation JANGLE. Ten of the original fifty were located near th 84th meridian and were equipped with high-volume air samplers. A samples were taken over a 24-hour period. Samples were air-maile nearby AEC installations where they were counted. These data wer assembled and tabulated at the AEC New York Operations Office.[6] office also operated six mobile ground stations, and during BUSTE made a few low-level filter flights along the 95th meridian. The personnel and portable equipment for the mobile stations were flo locations predicted to be under the cloud of debris. These teams exposed trays and gummed papers, usually for 12-hour periods, and obtained short exposure air-filter samples during and after the p of the airborne cloud.

The data from the AEC-Weather Bureau network of fall monitoring stations are included in Appendix A of this report. Th data from the mobile stations and the low-level flights have been used in the preparation of the report but in general have not bee included. These data are given in the New York Operations Office Report.

---

6 U. S. Atomic Energy Commission, op. cit.

primarily along the 84th meridian. These flights are denoted by the code name LARK WILLIAM. The planes were dispatched on the basis of meteorological predictions of the cloud trajectory. These planes made passes through the cloud as it progressed across the meridian, but here again the major portion of the activity was usually above flight altitude, and all flight altitudes were well above the surface. A few flights, termed LARK BAKER SPECIAL and LARK CHARLIE SPECIAL, were made southward and southwestward from Sacramento, California, to cross the clouds which moved in that direction.

All data obtained from these long-range detection flights are included in this report. Maps containing the data from each flight are included in Chapter 3 in the discussion of the appropriate burst.

2.2.4 Surface Sampling Operations

The AEC, New York Operations Office, with the aid of the U.S. Weather Bureau, installed fallout trays and gummed papers at 50 stations in the United States for Operation BUSTER, and 10 more for Operation JANGLE. Ten of the original fifty were located near the 84th meridian and were equipped with high-volume air samplers. All samples were taken over a 24-hour period. Samples were air-mailed to nearby AEC installations where they were counted. These data were assembled and tabulated at the AEC New York Operations Office.[6] This office also operated six mobile ground stations, and during BUSTER, made a few low-level filter flights along the 95th meridian. The personnel and portable equipment for the mobile stations were flown to locations predicted to be under the cloud of debris. These teams exposed trays and gummed papers, usually for 12-hour periods, and obtained short exposure air-filter samples during and after the passage of the airborne cloud.

The data from the AEC-Weather Bureau network of fallout monitoring stations are included in Appendix A of this report. The data from the mobile stations and the low-level flights have been used in the preparation of the report but in general have not been included. These data are given in the New York Operations Office Report.

---

[6] U. S. Atomic Energy Commission, op. cit.

CHAPTER 3

DISTRIBUTION OF RADIOACTIVE DEBRIS

3.1 BUSTER ABLE

Detonation of this weapon occurred on a 100-foot tower at 1400 GCT 22 October 1951, at about 4300 feet above sea level.

3.1.1 Initial Cloud Dimensions

Only six minutes were required for the BUSTER Able cloud to reach its maximum height of 8000 feet above sea level, at which time the base of the mushroom was at 6700 feet. As the cloud moved eastward over and beyond the first range of hills additional lifting and settling occurred so that the height varied between about 8000 feet and 10,000 feet. At eight minutes after detonation the cloud width was 5100 feet. A shallow cloud of dust reaching a height of about 300 feet above the ground was raised near the tower.

3.1.2 Initial Cloud Track

Beta and gamma activity was so low in this cloud that the tracking airplane was unable to make any measurements. After following it visually for about an hour, long enough to determine its initial direction of motion with accuracy, the tracker returned to base.

3.1.3 Long-Range Cloud Path

There were no long-range detection flights. Figure 3.1 shows the trajectory of the top of the cloud, i.e., at 8000 ft msl. Positions are shown at 6-hour intervals, and the time is indicated daily for the 0000 GCT position. This path was determined entirely from the observed winds at levels near the top of the cloud. The areas shown in Figure 3.2 represent the approximate distribution of the material in the upper part of the cloud, say from 6000 to 10,000 feet, at 1800 GCT on four successive days beginning 22 October 1951. Diffusion, especially over the Rocky Mountains, is assumed to have spread the cloud upward to about the 10,000-foot level. It should be emphasized that the areas shown are only approximate since they are based on a meteorological trajectory which is subject to error, and on an estimated rate of spread.

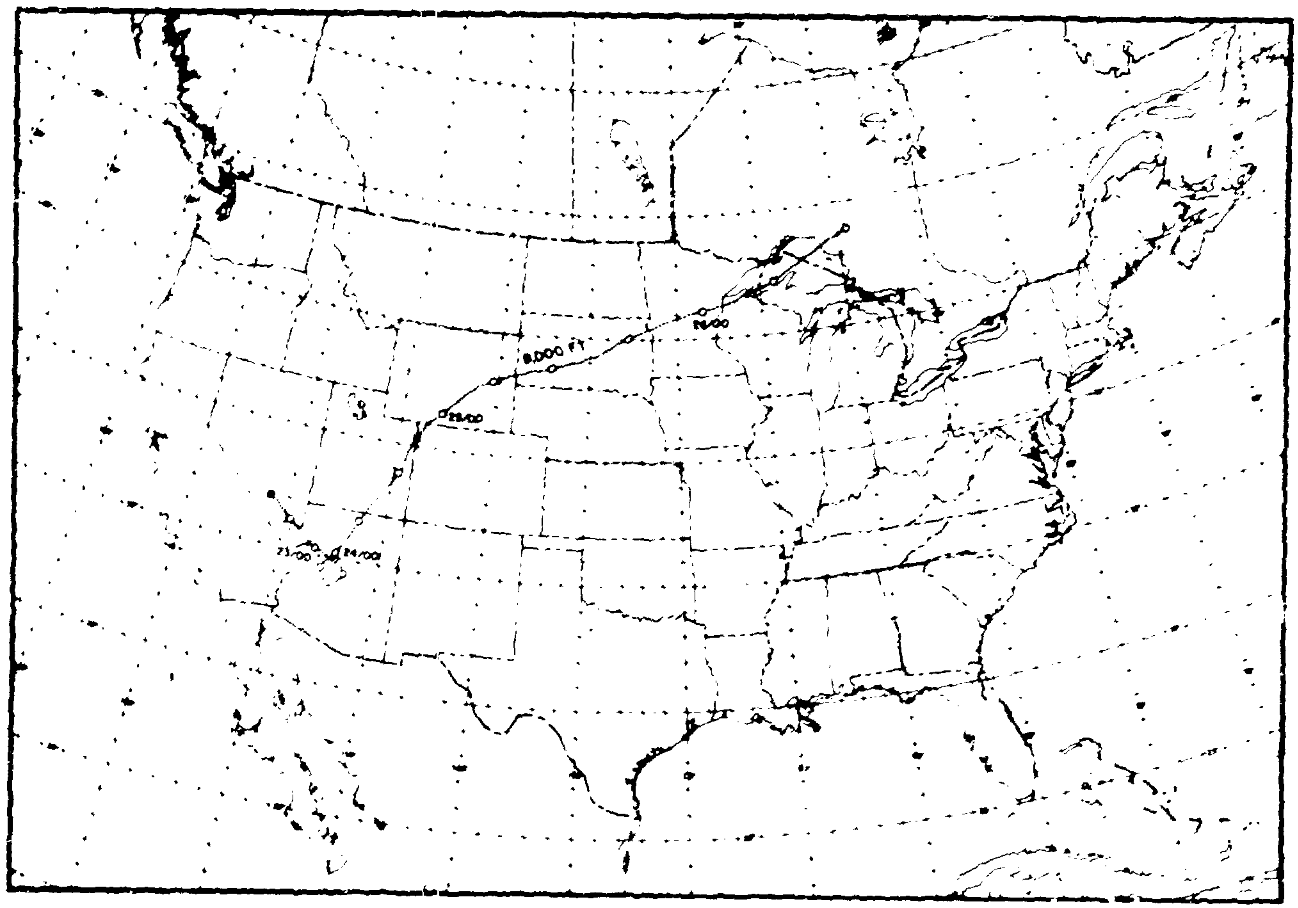


Fig. 3.1 Trajectory of the Primary Cloud from BUSTER Able

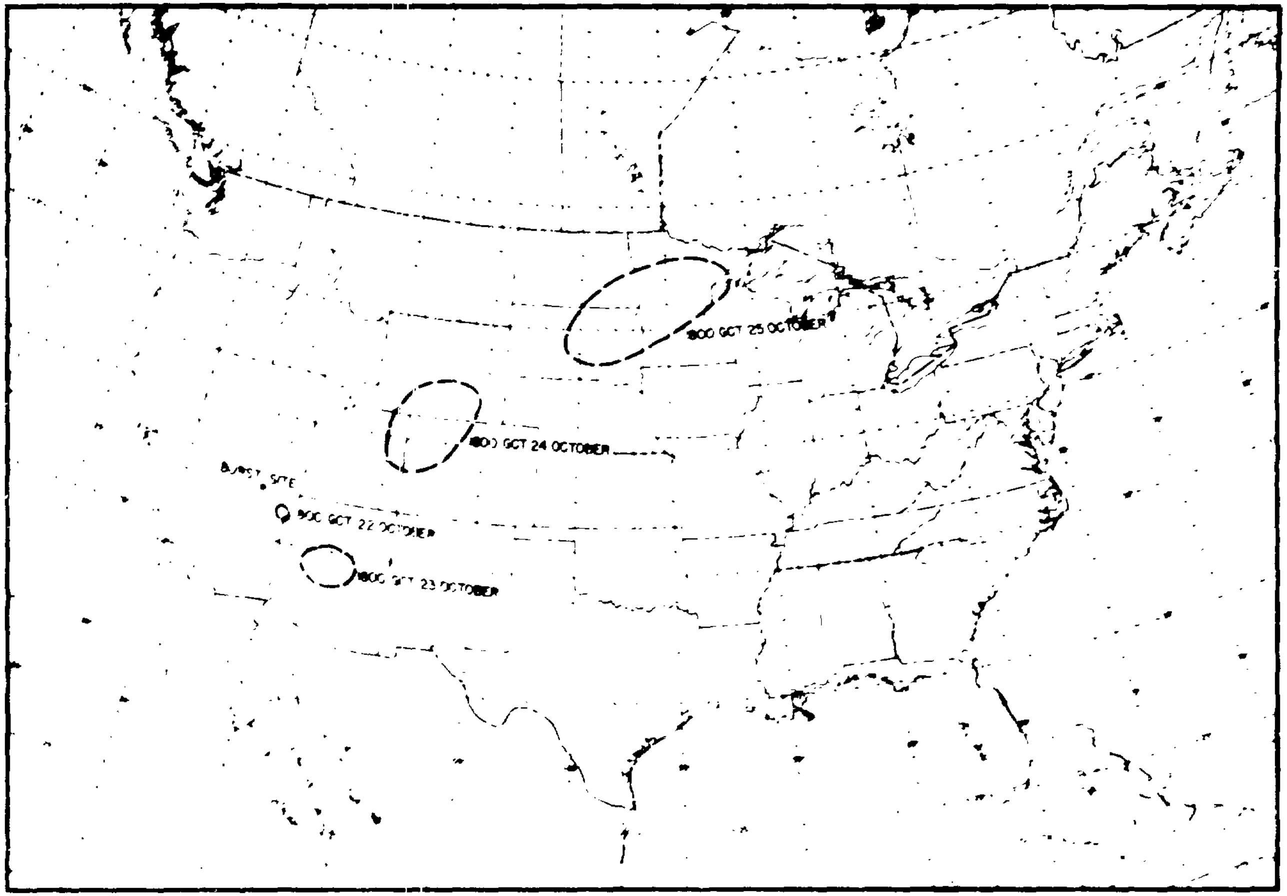


Fig. 3.2 Areas of Debris at 8,000 Feet from BUSTER Able

3.1.4 Distribution of Radioactive Debris at the Ground

Due to the absence of detectable beta and gamma radiations from the debris of this cloud, no ground contamination is attributed to it. No measurements of possible alpha contaminations were available.

3.2 BUSTER BAKER

Detonation of the weapon occurred at 1520 GCT 28 October 1951. The weapon was dropped from an airplane and the detonation altitude was determined to be 5400 feet msl (1100 feet above the ground).

3.2.1 Initial Cloud Dimensions

The Baker cloud reached a maximum height of about 31,700 feet msl in 15 minutes. The mushroom was broken up in rising the final few hundred feet and the reddish-brown bomb debris appeared to exist in moderate concentration from 13,000 feet to the cloud top. Below this height, any brownish debris was obscured by the thick gray dust column. No observations were made of mushroom width.

3.2.2 Initial Cloud Track

The movement of the debris toward the southwest is illustrated in Figure 3.3. Lines are shown, outlining the leading edge of measurable radioactivity at one-hour intervals. The leading edge was the highest portion of the cloud, since wind speeds increased with altitude to above the top of the mushroom. As the airborne instruments respond only to activity within a couple of thousand feet, vertically, and the airplane was at about 20,000 feet, the progression of the higher portions was determined by visual observation and meteorological trajectories. The slower air flow at low altitudes resulted in a trailing of debris back almost to the Test Site. Most of the debris moved through the area indicated, except the very lowest portion of the cloud, which was carried so slowly that it may have been subjected to a somewhat different wind field before it reached the coast. Although this was the portion of the cloud which offered the greatest hazard to personnel at ground level, it was not tracked. The tracking airplane completely circled a portion of the cloud at 20,000 feet at 2030 GCT. It is probable that this was the main cloud stem at and near this altitude. The diameter of the slice was about 13 nautical miles, representing a mean rate of increase of the diameter, to that point, of about three knots. This rate compares well with similar measurements on other cloud .

3.2.3 Long-Range Cloud Path

The long-range trajectories for the Baker cloud are shown in Figure 3.4. Each trajectory represents the movement of the primary cloud at a particular level. These trajectories are based on meteorological data and on the results of the detection flights. It can be seen that at 700 mb (approximately 10,000 feet) and at all higher levels the primary cloud curved around the low pressure center off the coast of Southern California before crossing the United States. This low was nearly stationary and was well developed to elevations above the cloud top. Some of the material in the lowest few thousand feet moved farther westward over the Pacific and did not return to the United States until many days later. Also, as is indicated by the splitting of the 500-mb trajectory in the vicinity of the low center, it is believed that some of the material at this and probably at other levels remained within the cyclonic circulation for perhaps another day before moving inland with the low center.

The plotting model for data from all long-range detection flights is given in Figure 3.5. The first flights pertinent to the Baker cloud were the two LARK BAKER flights shown in Figures 3.6 and 3.7. The high activity, particularly that encountered on the first of these flights, was probably due to fallout from higher levels. The first LARK WILLIAM flight (Figure 3.8) detected no activity above background. The northern part of this flight was either just ahead of, or more probably one or two thousand feet below, the fast-moving upper portion of the cloud. The LARK WILLIAM flights 2 and 3 (Figures 3.9 and 3.10) each made two passes through the debris from the Baker cloud. These four passes through the cloud occurred within a four-hour period and were all at different levels. At none of these levels, from 10,000 to 25,000 feet, did the aircraft pass completely through the cloud. However, it is felt that the area of highest activity was intercepted at each of the levels, since the air just a few miles north of the turning points of the flights had an entirely different trajectory than the air containing the radioactive debris. There was probably no radioactive debris from this burst north of 43°N.

With the aid of detection data from the LARK WILLIAM flights and meteorological trajectories at the standard isobaric levels a time-altitude cross section (Figure 3.11) was drawn depicting the axis of the cloud as it passed the 84th meridian. In addition to the Baker cloud the Charlie cloud (see Section 3.3) is shown, since it reached the flight line shortly after the Baker cloud. It should be emphasized that this diagram at all times pertains to the latitude where the highest concentrations at the 84th meridian occurred. For example, the cores of both clouds passed the flight line initially at around 40°N, while the highest concentrations on the next day were found at around 35°N. In the figure the detection data is denoted only as to order of magnitude by the appropriate hatching. The circles represent the primary cloud at the standard meteorological levels. The heavy line joining the circles, then, represents the core of the cloud. This core, at least in the layer through which the mushroom initially extended, probably contained concentrations of more than 1,000,000 cpm per half-hour flight. Lines denoting a moderately high concentration (10,000 cpm) and a concentration (200 cpm) above the general background prior to the bursts are shown. Except in the vicinity of actual detection data these lines are only approximate. The concentration in the lowest few thousand feet was inferred from the data at higher levels and especially from the AEC air filter data at the ground, given in Appendix A. As will be discussed later the ground detection was complicated by many factors and is hard to interpret. Nevertheless, air filter stations near the flight line, particularly Cincinnati, provided useful information. At this station there was an indication of decreasing residual activity from the third Russian burst prior to the arrival of the Baker material at the ground. Then, on the filter exposed from 0750 GCT 1 November to 0640 GCT 2 November, a count of 570 d/m/meter^3 was observed, showing the arrival at the ground of very high concentrations of radioactive debris sometime during that period.

For the Baker burst and for the remaining bursts as well, an attempt has been made to delineate the areas of radioactive material at several upper levels at or near which there were detection flights. Figures 3.12-3.14 show maps of the material for 1800 GCT 31 November at the 400-, 500- and 700-mb levels, respectively. Again isolines for 10,000 cpm and for 200 cpm are shown. These areas were determined by extrapolating detection data, by means of meteorological trajectories, ahead or backward in time to 1800 GCT on the 31st. Meteorological trajectories from the burst site and estimates of fallout and diffusion were also used in determining these areas of contamination. Except near the flight line these areas must be considered as rough approximations only. The areas occupied by the Charlie cloud at this time at the three levels are also shown.

3.2.4 Distribution of Radioactive Debris at the Ground

Debris from the Baker burst first appears on the map of ground contamination for 29 October (Figure A.11) over California, with a very high concentration at Santa Maria, which was very nearly beneath the path of the cloud at most upper levels. The contaminated areas in the eastern part of the country and in the extreme Northwest are from the third Russian burst and are generally associated with rainfall.

On the next day, as shown in Figure A.12, the sample collected at Topeka, Kansas, between 0800 GCT 30 October and 0400 GCT 31 October represents about the farthest eastward position of the

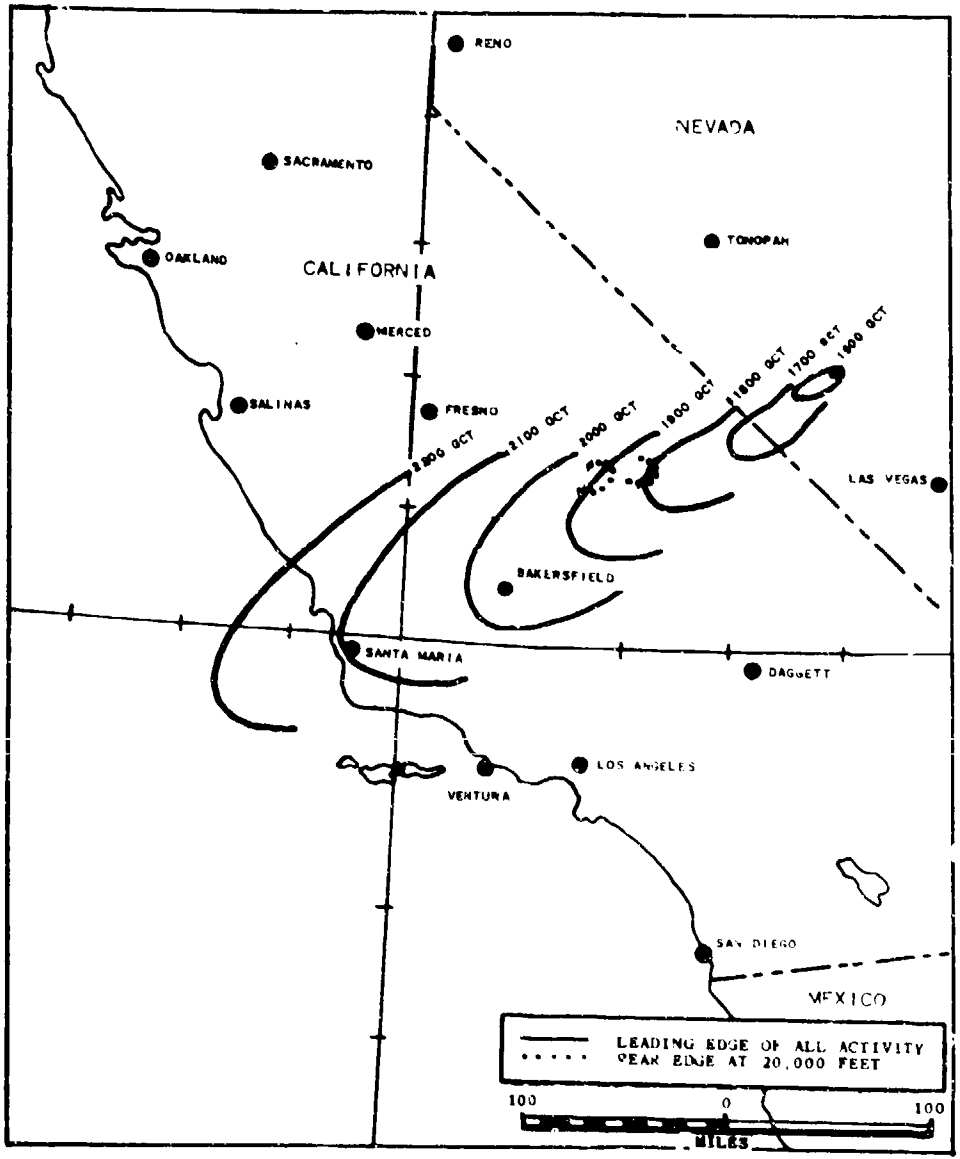


Fig. 3.3 Initial Movement of the BUSTER Baker Cloud. Detonation at 1520 GCT 28 October 1951; maximum height, 31,700 feet.

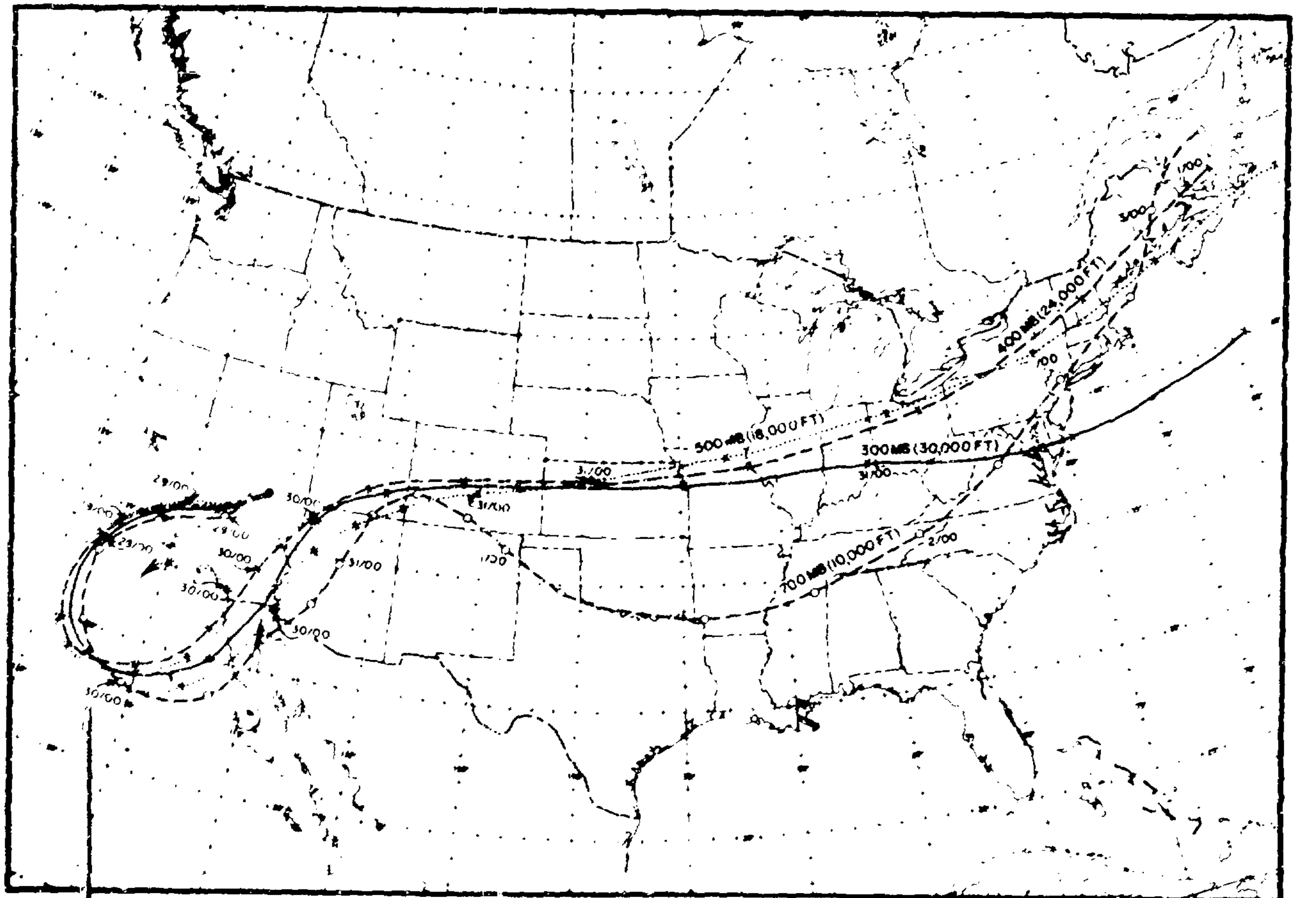


Fig. 3.4 Trajectories of the Primary Cloud from BUSTER Baker

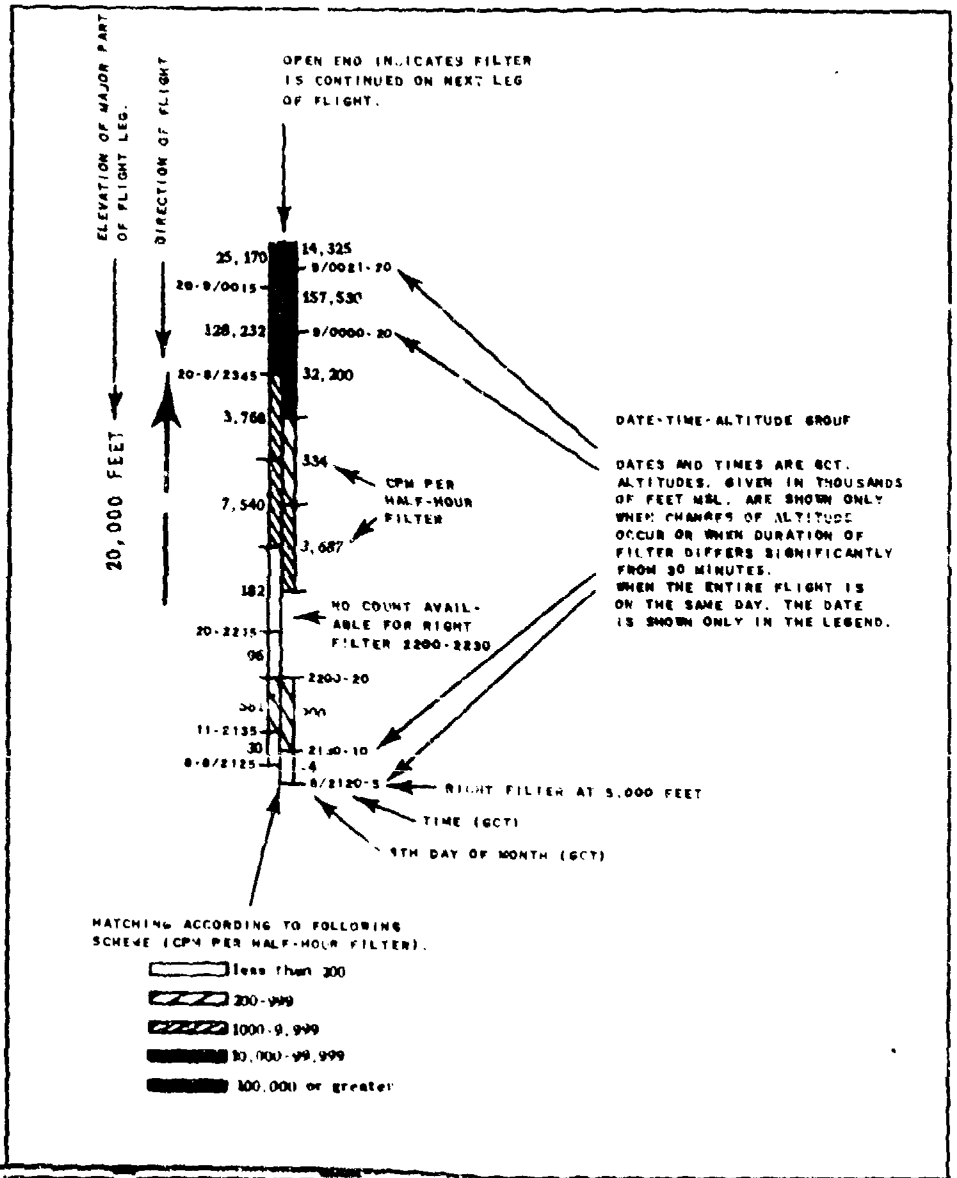


Fig. 3.5 Plotting Model for Long-Range Flight Data

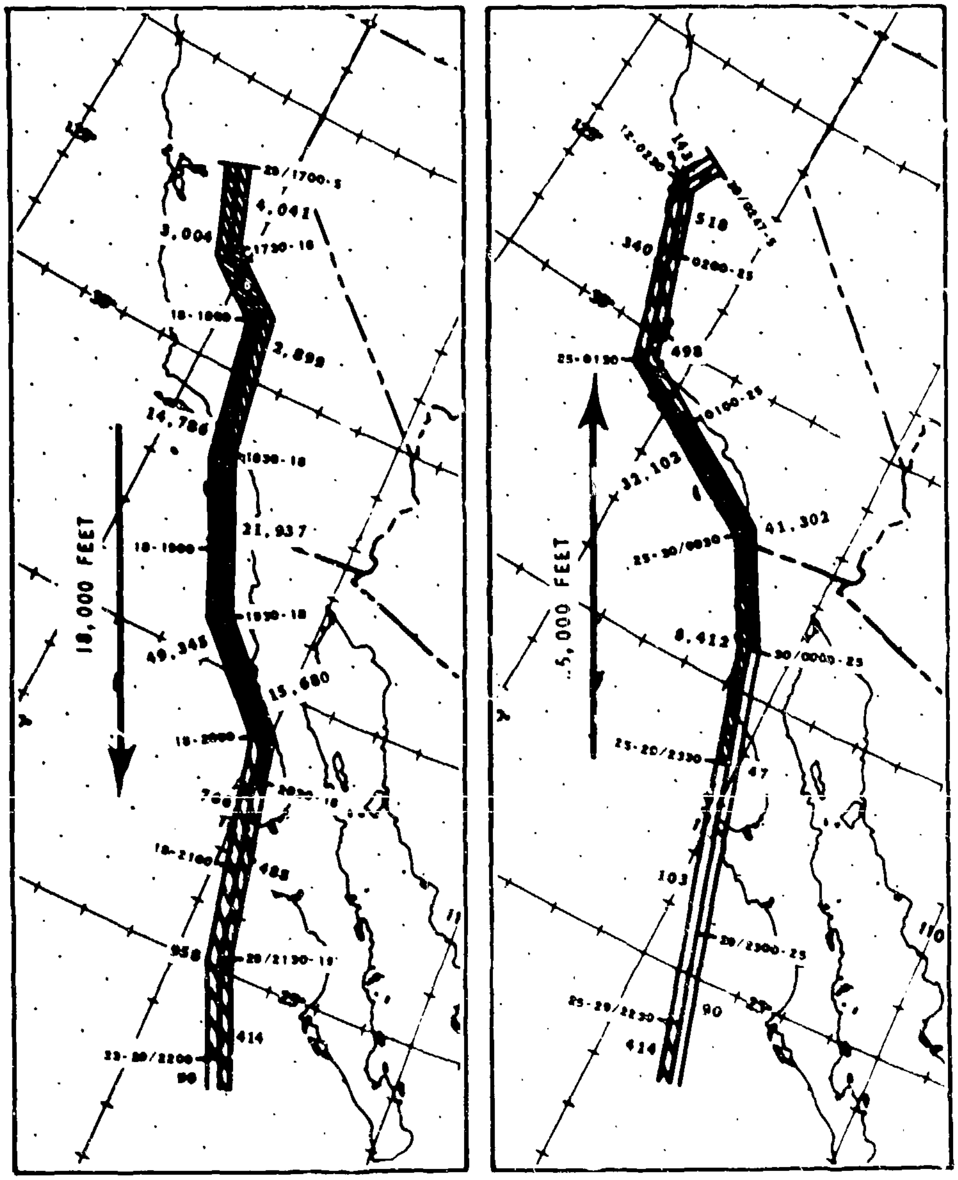


Fig. 3.6 LARK BAKER SPECIAL 1, 29-30 October 1951

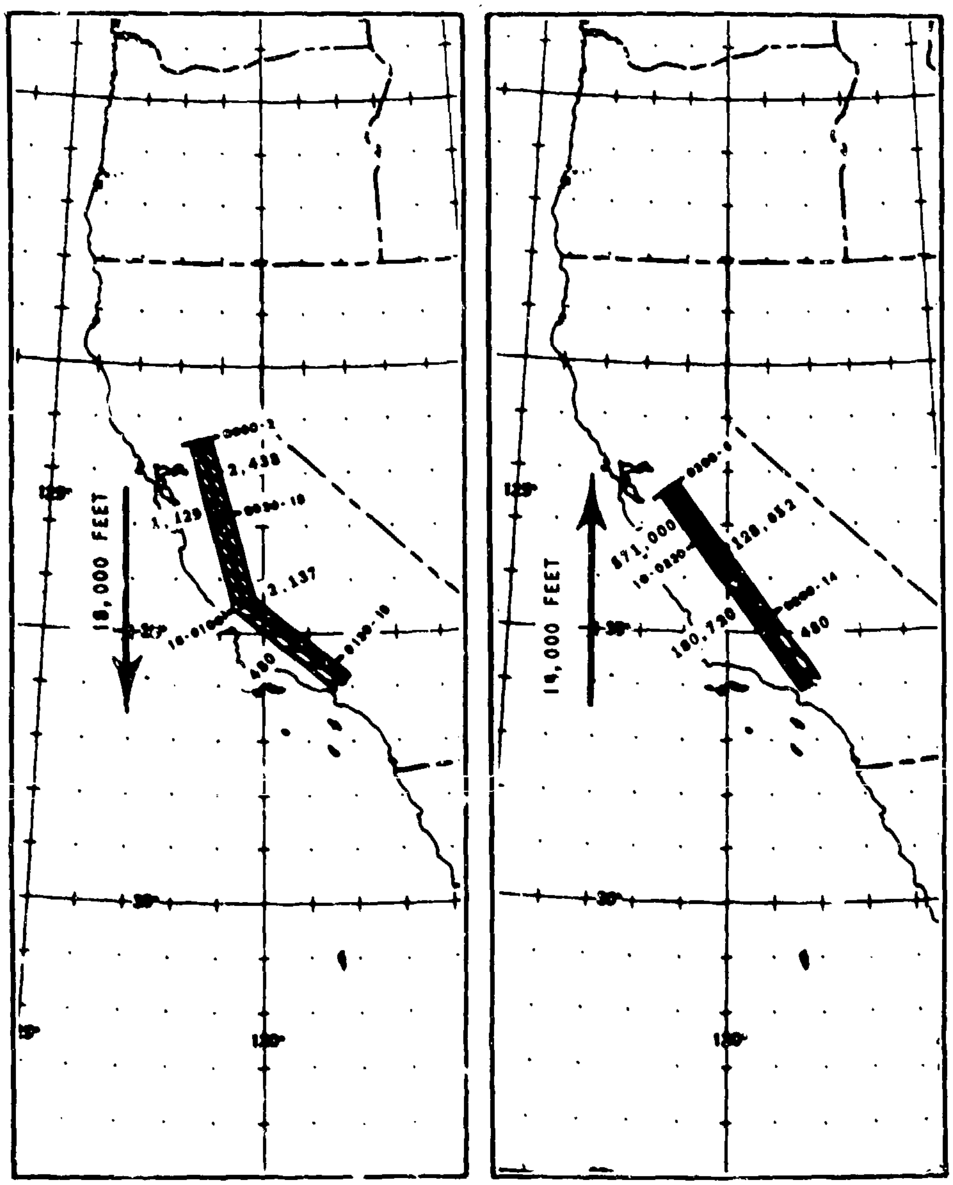


Fig. 3.7 LARK BAKER SPECIAL 2, 30 October 1951

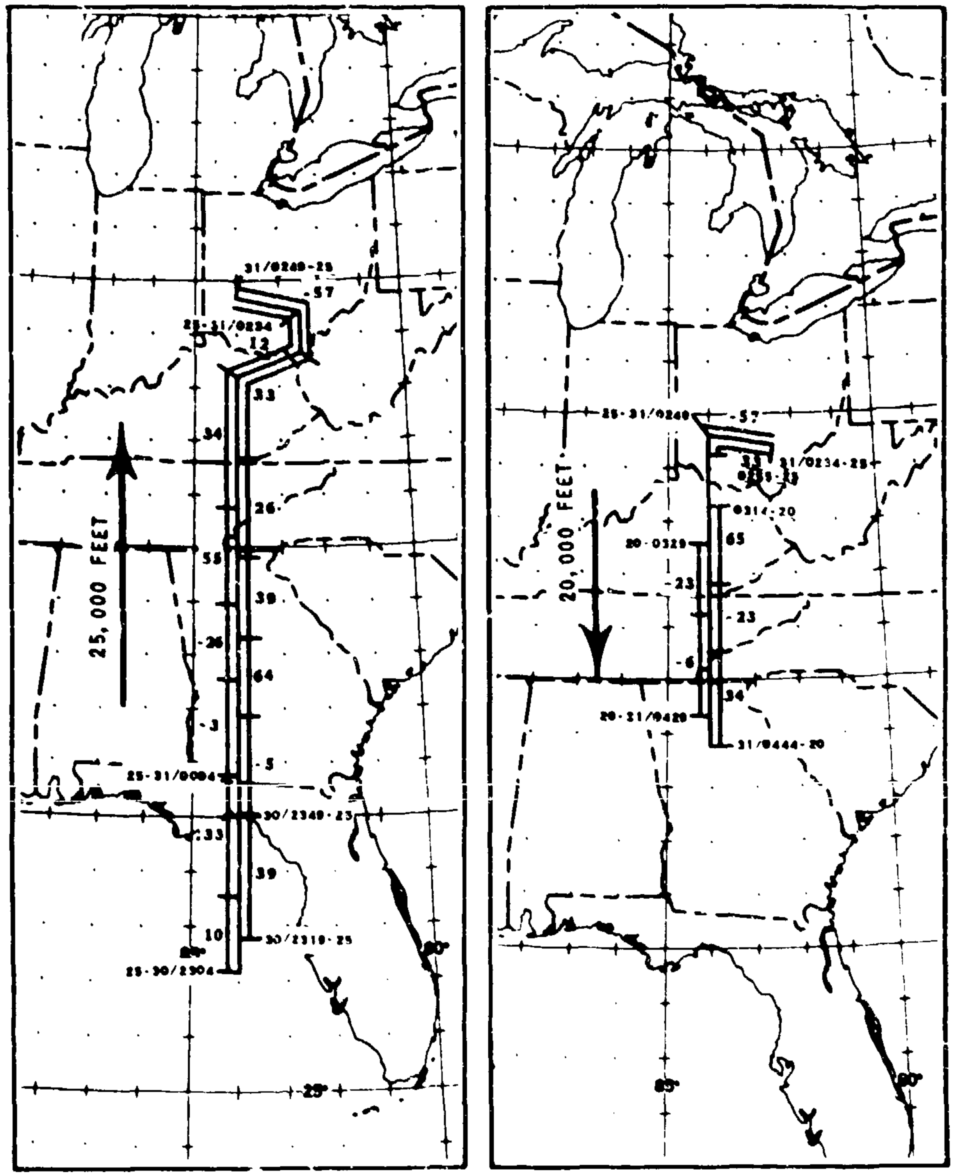


Fig. 3.8 LARK WILLIAM 1, 30-31 October 1951

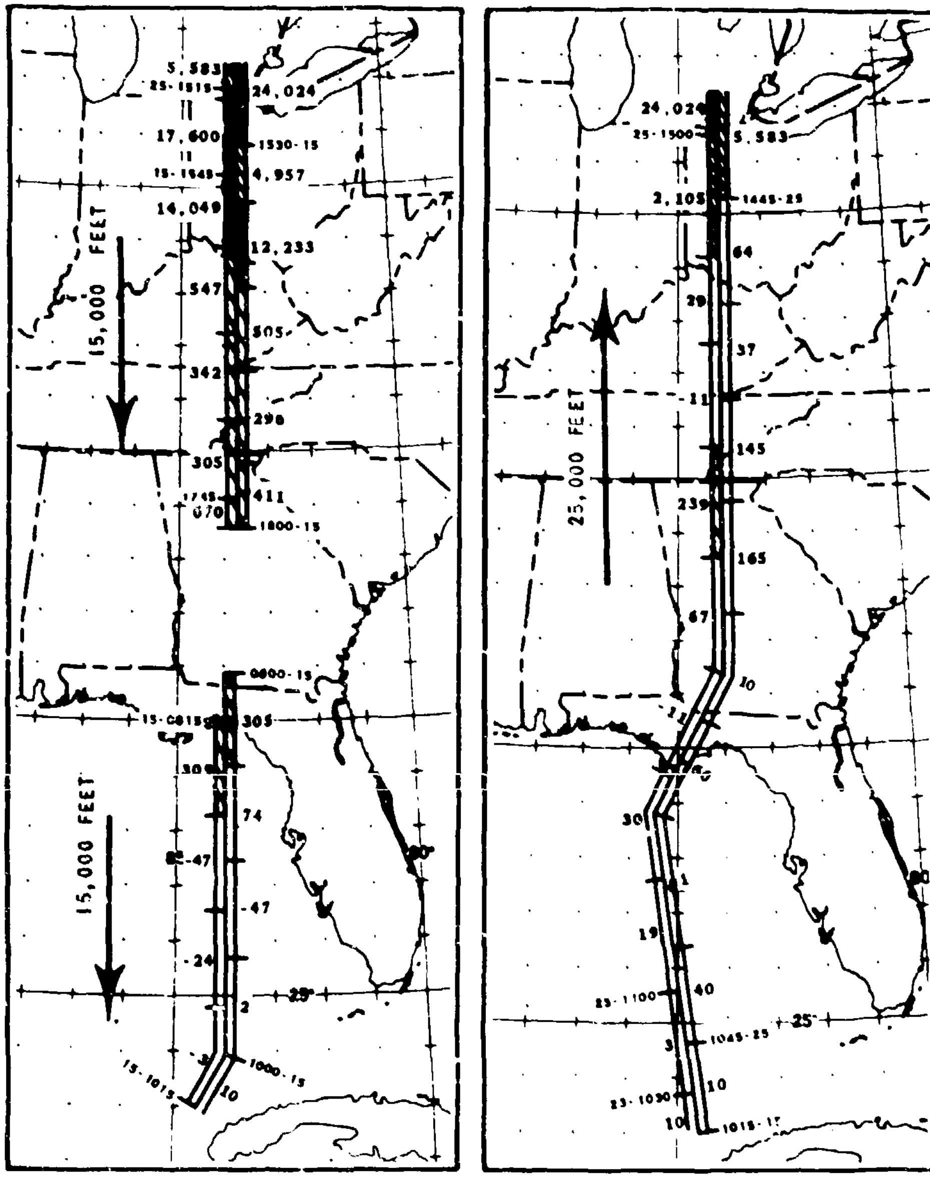


Fig. 3.9 LARK WILLIAM 2, 31 October 1951

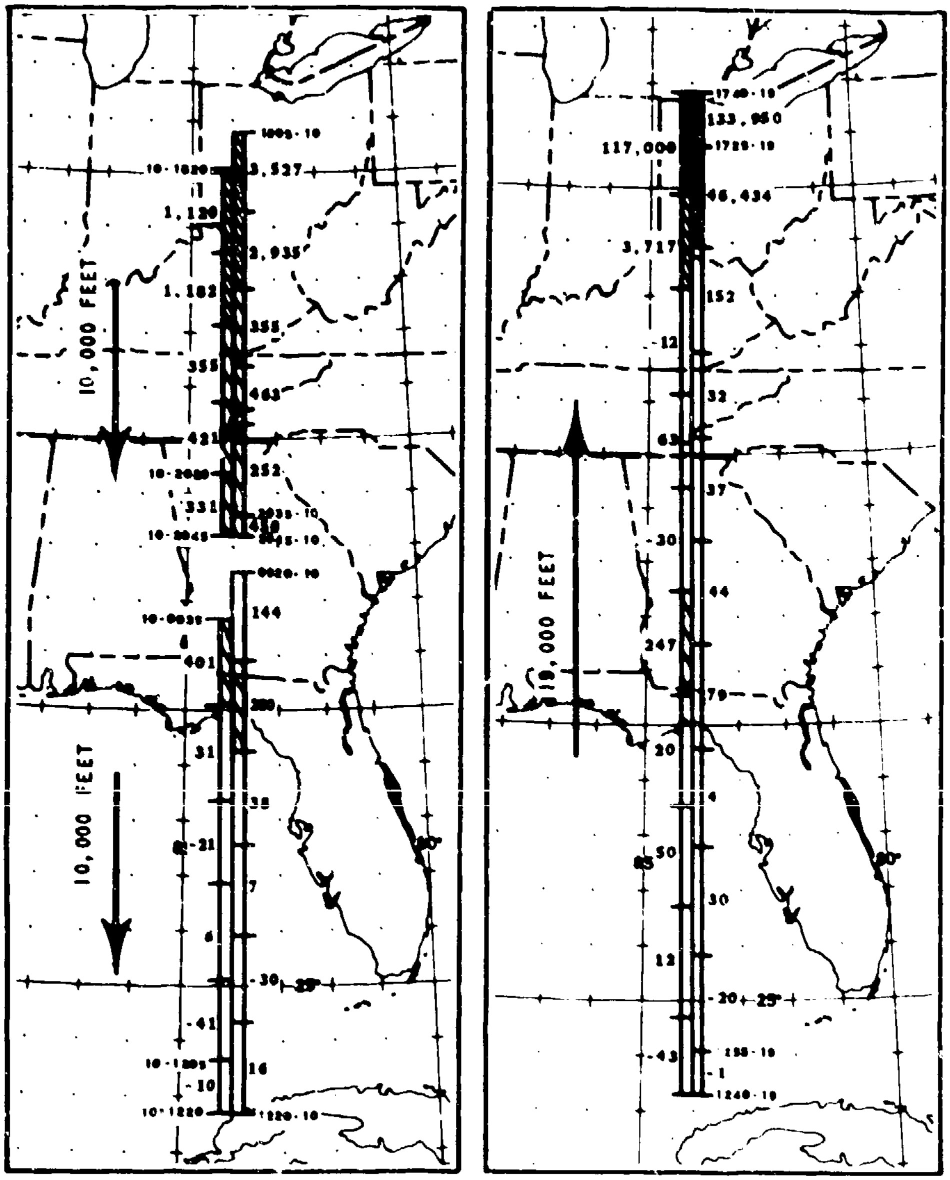


Fig. 3.10 LARK WILLIAM 3, 31 October 1951

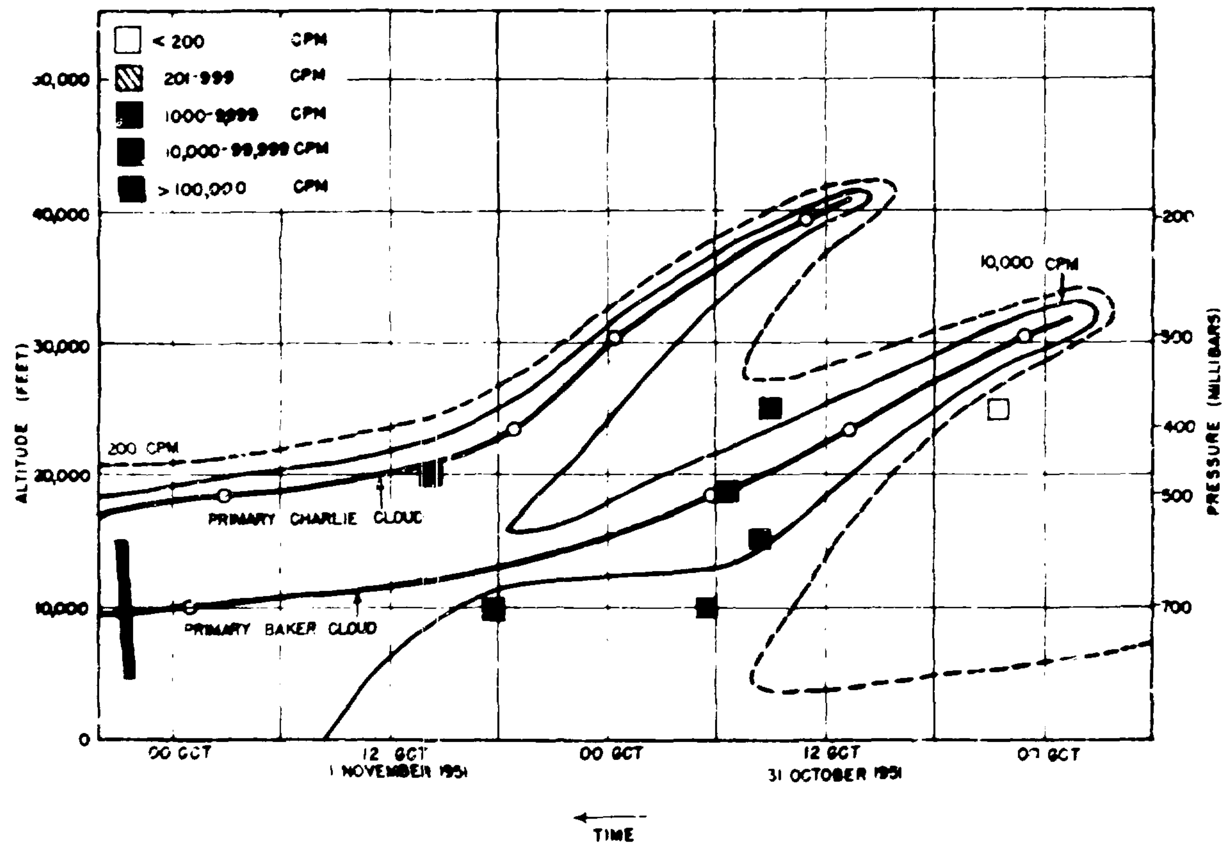


Fig. 3.11 Time-Altitude Cross Section at the 84th Meridian for Baker and Charlie

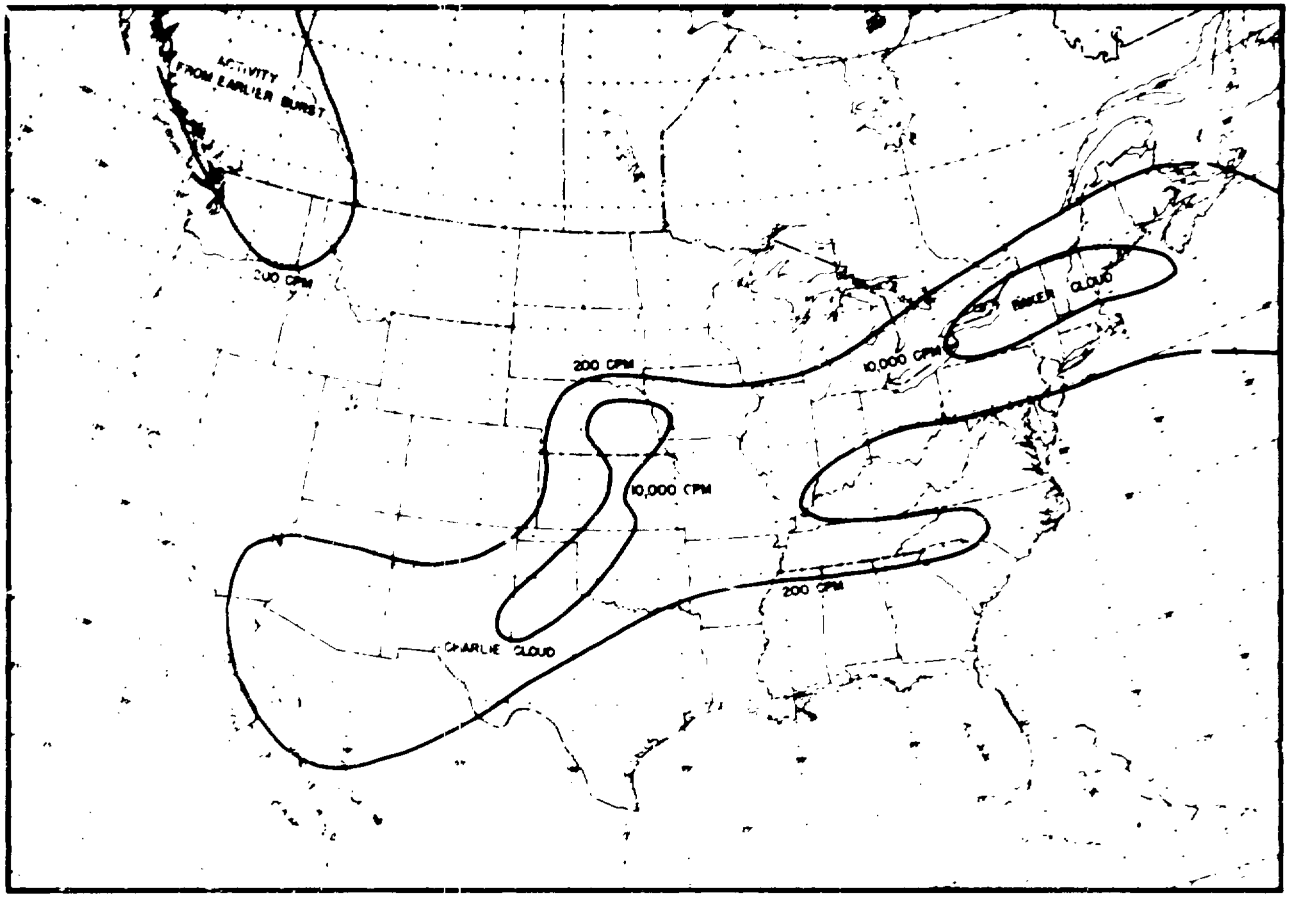


Fig. ?.12 Areas of Radioactive Debris at 400 mb (24,000 Feet) at 1800 GCT 31 October 1951

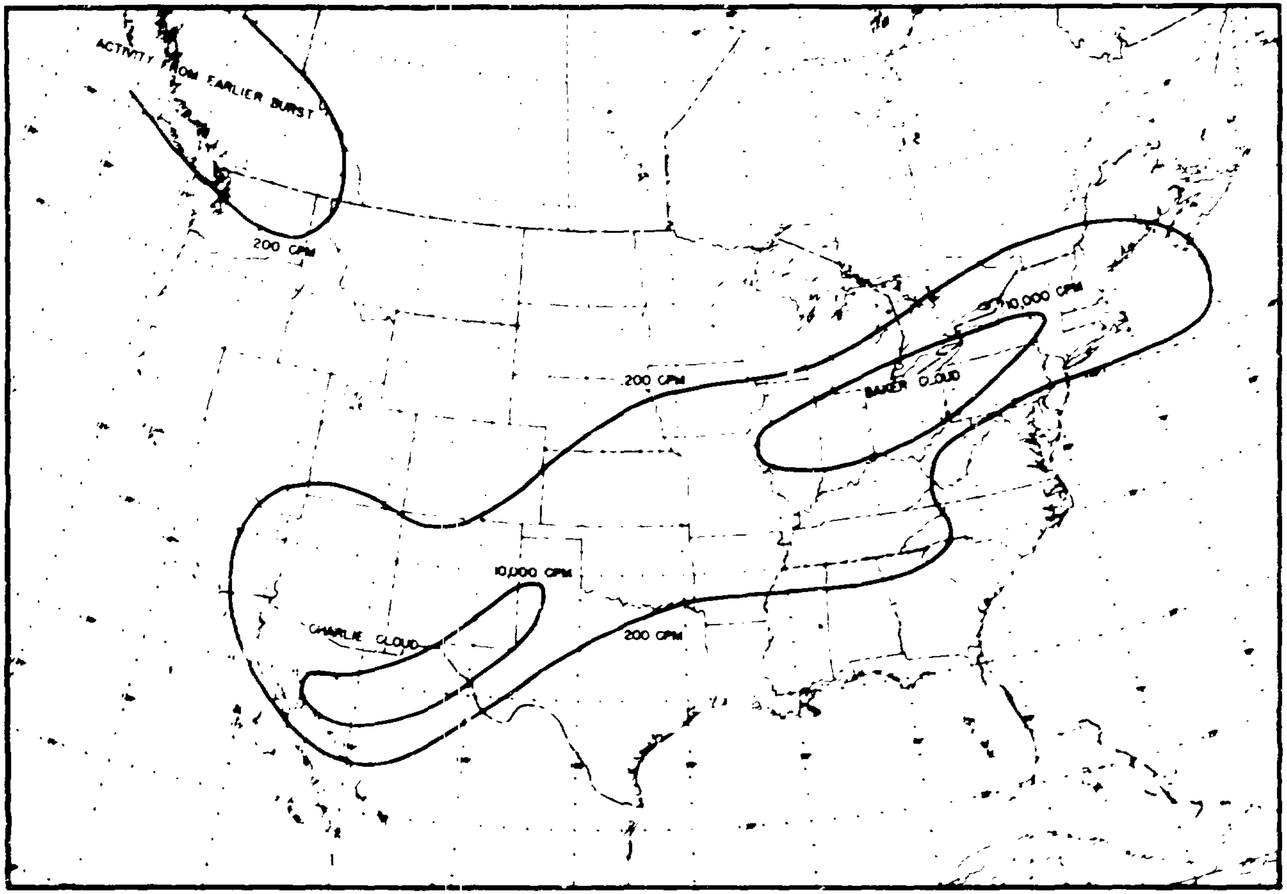


Fig. 3.13 Areas of Radioactive Debris at 500 mb (18,000 Feet) at 1800 GCT 31 October 1951

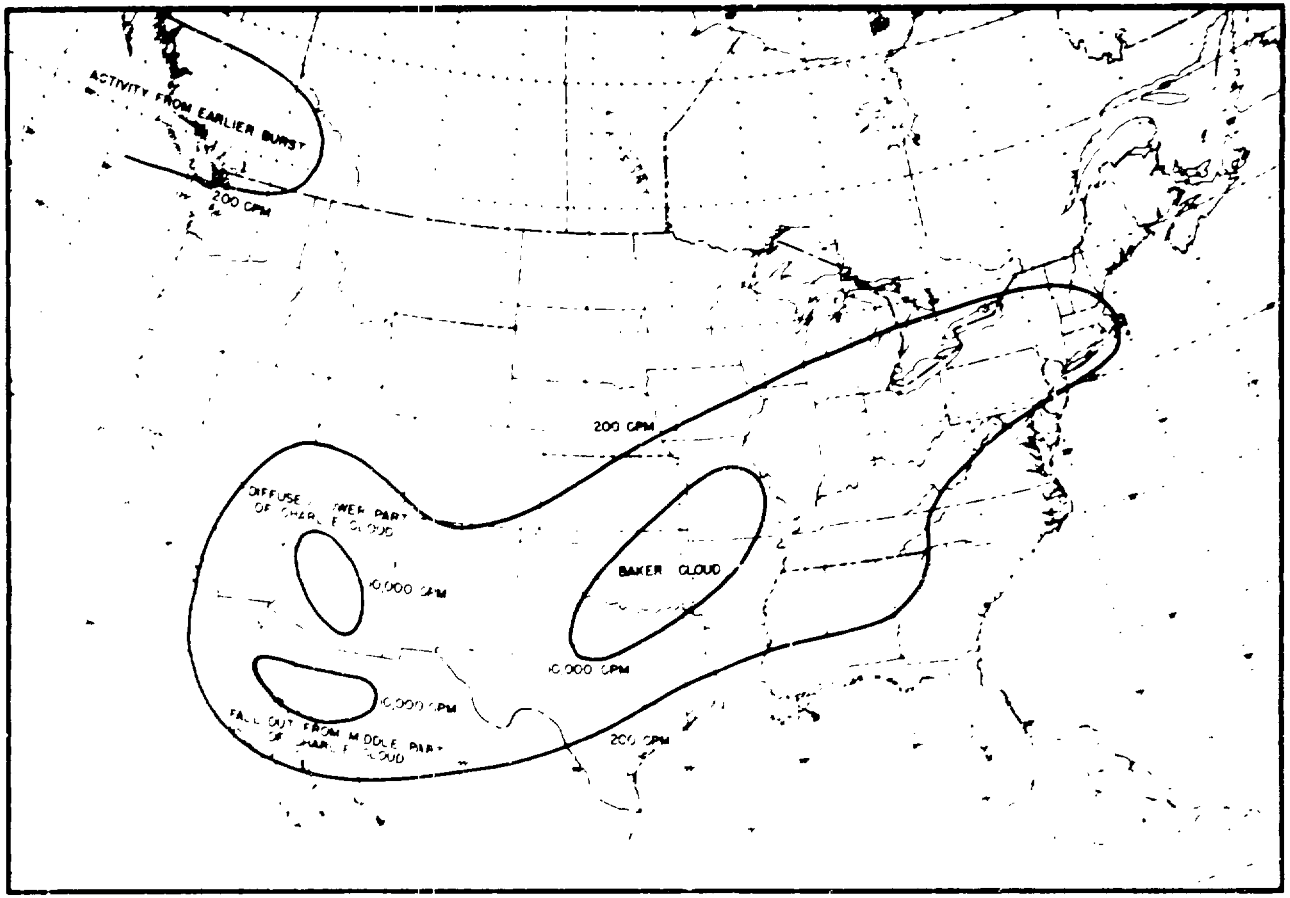


Fig. 3.1[illegible] Areas of Radioactive Debris at [illegible] mb ([illegible],000 Feet) at 1200 GCT 31 October 1951

Baker debris at the ground. This debris was undoubtedly brought downward in the light precipitation that occurred during the sampling period. The radioactivity found at stations east of the Mississippi River was very probably from the Russian burst.

In Figure A.13, the map for 31 October, the exact differentiation of material from Baker, Charlie, and the Russian burst is impossible, but it is probable that the belt of high concentrations in the eastern part of the country was due to a mixture of debris from the Baker and Russian bursts, while that in the central and western parts represented a mixture of material from Baker and Charlie. The surface distribution on this day corresponded quite well to the distribution at the 700-mb level, shown in Figure 3.14.

On the 1st and 2nd of November many areas of high concentration were reported, but, again, the material could not be identified as to burst.

3.3 BUSTER CHARLIE

The third weapon of this series, an air drop, was detonated at about 5400 feet msl (1100 feet above the ground) at 1500 GCT 30 October 1951.

3.3.1 Initial Cloud Dimensions

The cloud reached 12,000 feet above the surface in one minute and climbed to its maximum altitude in less than 12 minutes. The mushroom spread so rapidly and the cloud moved so nearly over the theodolite that it was impossible to determine the height accurately. The best estimate from all of the data seems to be about 41,000 feet for the top and 27,000 feet for the base of the mushroom. Eleven minutes after the explosion, the width of the mushroom was about 15,000 feet. A column of dust and debris trailed down to the surface, and this became distorted by the wind shear.

3.3.2 Initial Cloud Track

Figure 3.15 shows the outline of the cloud at one-hour intervals, as determined by aircraft data and meteorological trajectories. An unusual wind condition existed over the test area at and following detonation time. A deep low pressure system lay off the coast near San Diego with a very marked trough or shear line extending from this low northeastward across Southern Nevada. This trough lay to the northwest of the Test Site from the surface to

12,000 feet and to the southeast of the Site from 13,000 to 35,000 feet. This situation gave southwest winds in the lower levels and northeast winds above. Thus, the main part of the debris was carried southwestward, with a maximum speed of 32 knots at 20,000 feet. Above 36,000 feet, the shear line was again northwest of the Site so that the top of the cloud moved toward the northeast. For two hours after the burst the visible cloud was a spiral, originating at the Site, where a near calm existed near the ground. This spiral is shown in Figure 3.15 by the isochrones for 1600 and 1700 GCT. The highest part of the cloud could not be tracked after it was no longer visible. It and the lowest part were tracked for only about three hours. The first flight to track the cloud southwest of the Site aborted after 4-1/2 hours and the second tracker was unable to make its way around the cloud to track the forward portion. The leading edge after five hours therefore must be considered only approximate. The dotted lines show the trailing edge of activity in the neighborhood of the flight altitude, 20,000 feet, as determined by the second tracker.

3.3.3 Long-Range Cloud Path

The path of the Charlie cloud at intermediate levels, from 13,000 feet to 36,000 feet, was fairly similar to that of the Baker cloud in that it first had a southwestward course before heading eastward. However, as indicated in the discussion of the initial cloud characteristics, the top of the cloud and also the lowest part moved with an eastward component from the start. The trajectories for this cloud are shown in Figure 3.16.

The LARK CHARLIE SPECIAL flight, Figure 3.17, showed only background activity off the coast of Southern California. This indicates that at flight levels uncontaminated air had moved in behind the low center, which was moving northeastward. The first detection of the Charlie cloud along the 84th meridian was made at 20,000 feet on the southbound leg of LARK WILLIAM FOUR, shown in Figure 3.18. The 10,000-foot legs of this flight detected moderate concentrations of radioactive debris which might have been from the Charlie cloud but which were more probably from the Baker cloud. The 20,000-foot detection on this flight occurred through a fairly broad belt with two peaks of more than 100,000 cpm. This double maximum is quite different from the narrower, single peak of activity found for the Baker cloud.

The different paths followed by the debris at the 300-mb level and at the 400-mb level, as shown in Figure 3.16 suggest the explanation of the double maximum. The 300-mb trajectory crossed the flight line at 43°N, not far from the northern peak activity. Probably this peak was caused by debris, originally above the 300-mb level, which moved along a path similar to that of the 300-mb trajectory until it had been carried farther to the north than the lower-level debris. If this material had a gradual downward motion, bringing it to the 20,000-foot level near the flight line, it could account for the northern peak in activity.

The southern maximum occurred near the intersection of the 400-mb trajectory with the flight line and only a few hours after the primary cloud at this level had passed. Thus this activity can be attributed to a primary cloud for the 20,000-foot level or, better, to material that had fallen only a few thousand feet before reaching the flight line. This is an excellent example of the spreading of a contaminant in the atmosphere by the combined effects of the wind shear with height, and vertical motions.

The passage of the core of the Charlie cloud at the 84th meridian is shown with the Baker cloud in Figure 3.11. As with the Baker cloud, the inferred times of passage of the primary cloud at various levels and the nature of the fallout curtain seem reasonable. Data from the LARK WILLIAM FIVE flight (Figure 3.19) show that fairly strong concentrations of material occurred at least in the layer from 5,000 to 15,000 feet. This debris is probably from the Charlie cloud, but could be a mixture of material from Baker and Charlie. Similar concentrations were found in these levels on the initial climb of the LARK WILLIAM SIX flight, shown in Figure 3.25 with the discussion of the Dog cloud.

Figures 3.20, 3.21 and 3.22 depict the areas covered by the Charlie and other clouds at 400, 500, and 700 mb at 1800 GCT 1 November. The considerable extent of moderately high concentrations from the Charlie cloud is perhaps more apparent on these figures than on the maps of the individual detection flights. This spreading stems from the large difference in the wind speeds and directions at various levels, shown by the spread of the trajectories, coupled with vertical diffusion and fallout. Lateral diffusion at a particular level would not result in a spreading of this magnitude.

3.3.4 Distribution of Radioactive Debris at the Ground

Certainly much of the material collected at the ground during the week following this burst was from the Charlie cloud, but the presence of debris from other bursts made it impossible to attribute any individual sample to a particular burst. A further discussion of the mixing of debris from Baker, Charlie, and Dog clouds is given in 3.4.4.

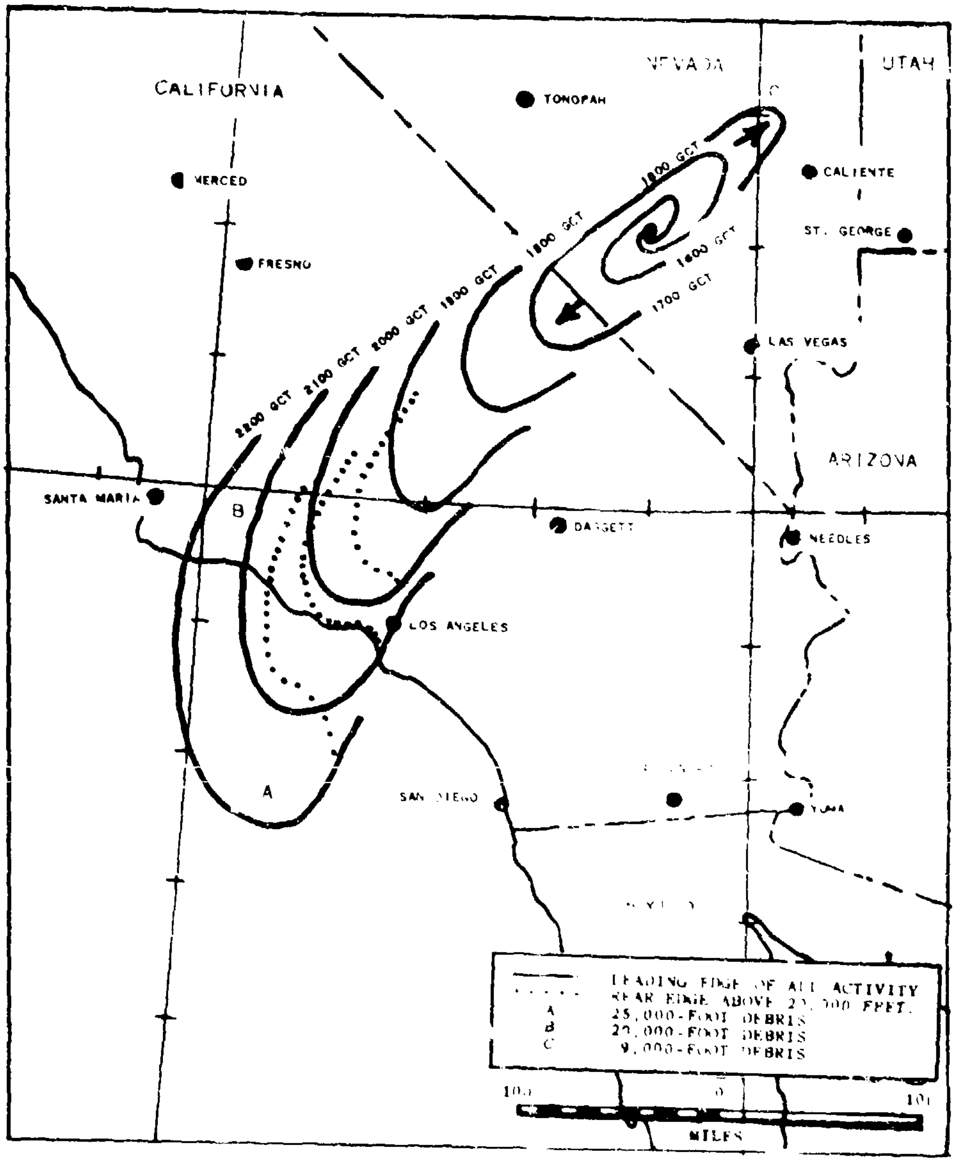


Fig. 3.15 Initial Movement of the BUSTER Charlie Cloud. Detonation at 1500 GCT 30 October 1951; maximum height, 41,000 feet.

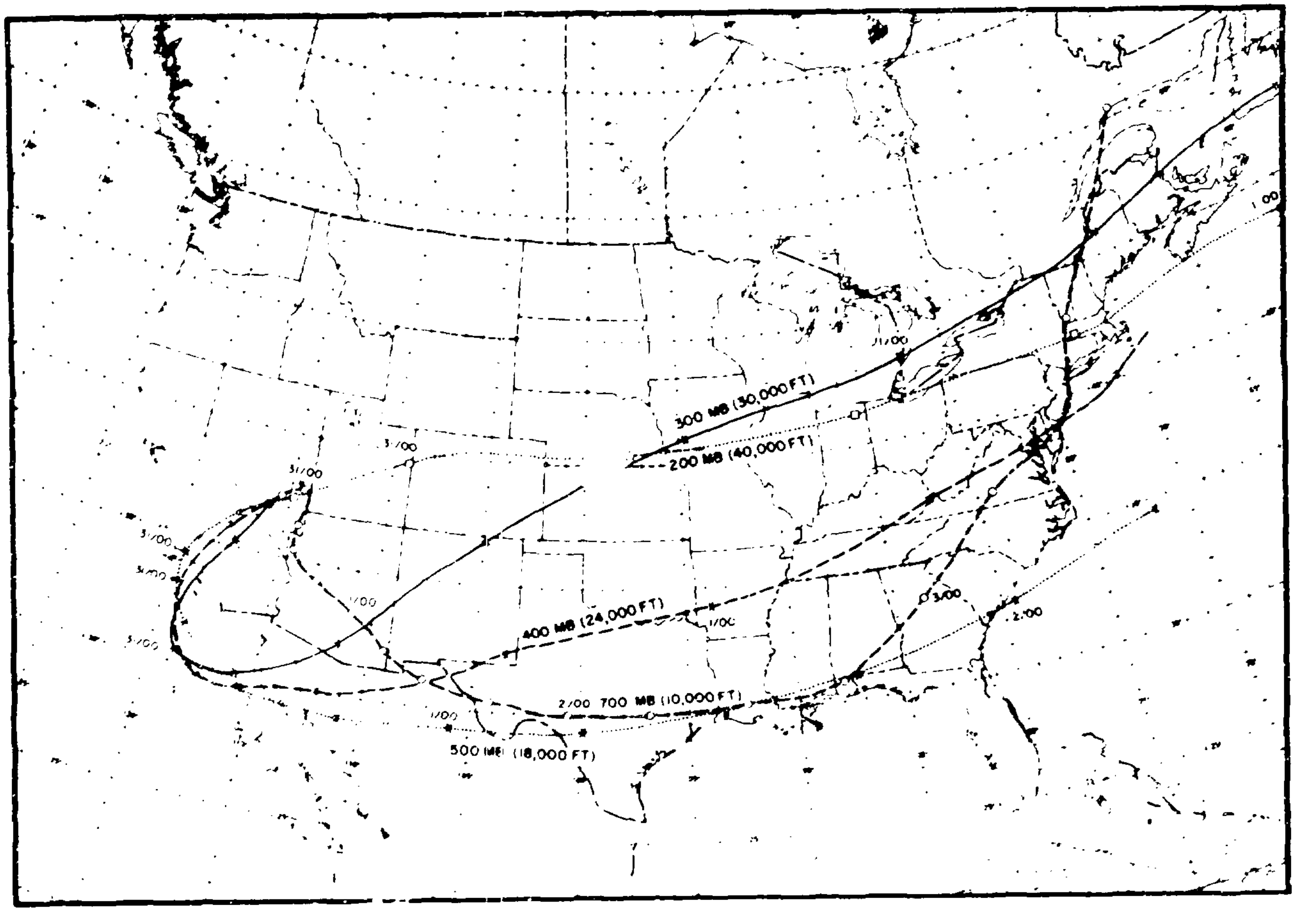


Fig. 3.16 Trajectories of the Primary Cloud from BUSTER Charlie

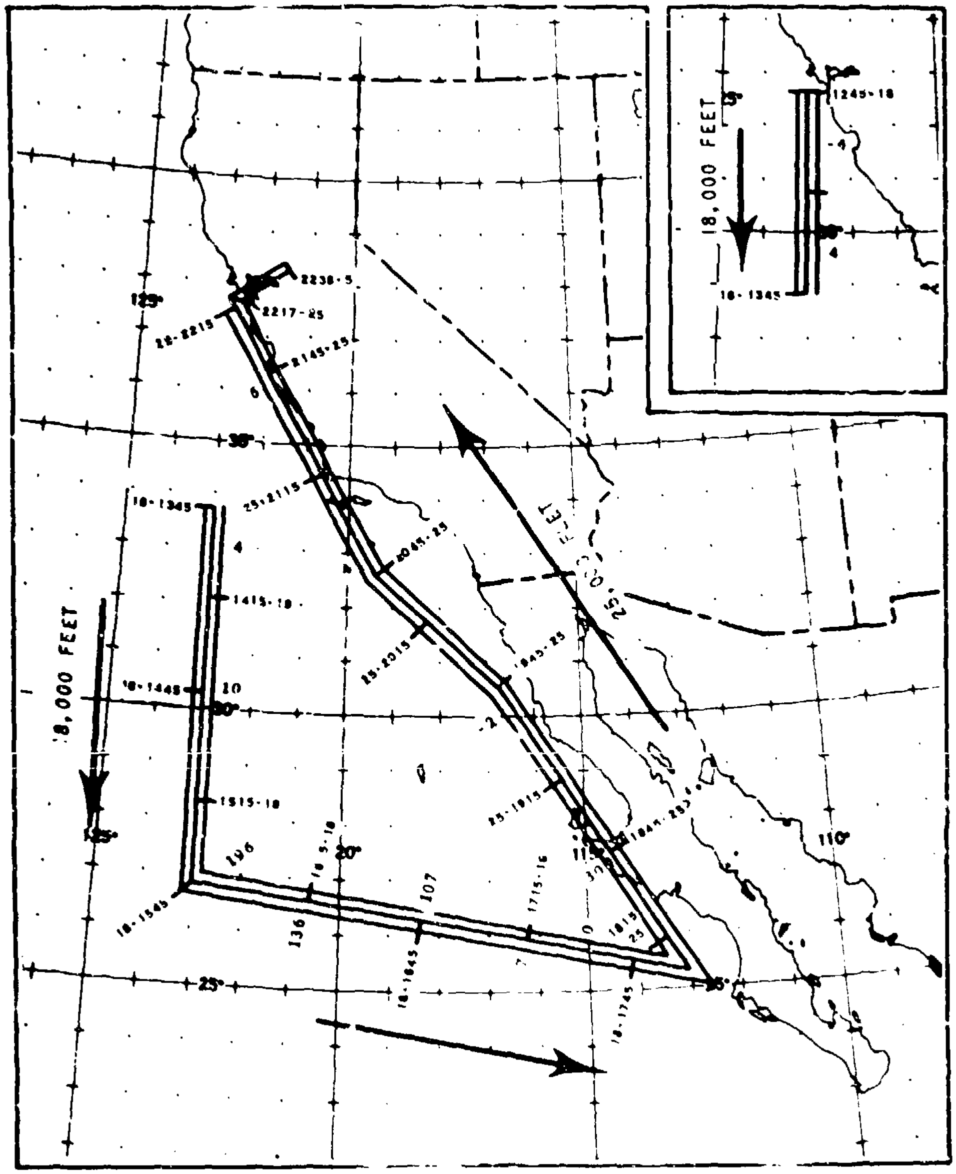


Fig. 3.17 LARK CHARLIE SPECIAL 1, 31 October 1951

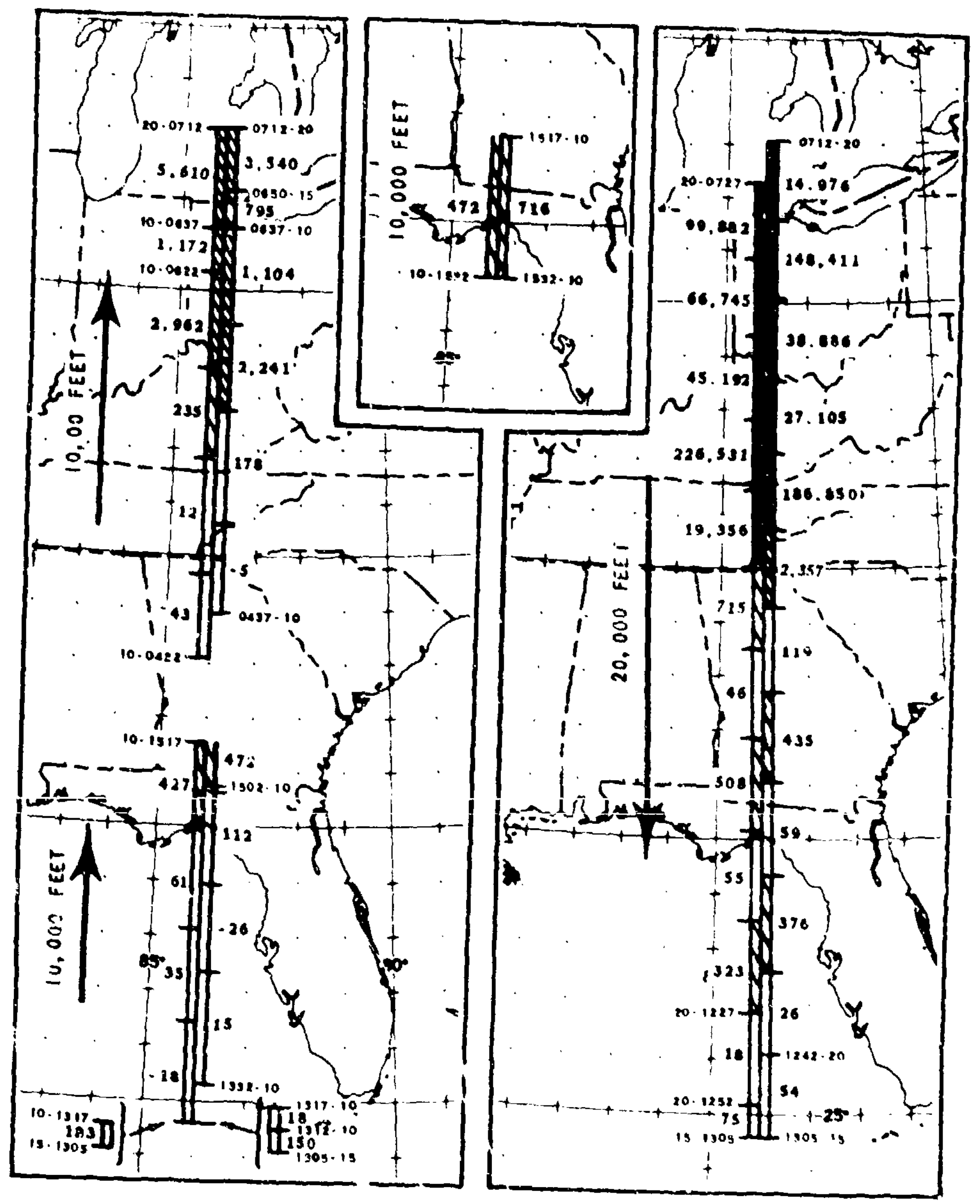


Fig. 3.18 LARK WILLIAM 4, 1 November 1951

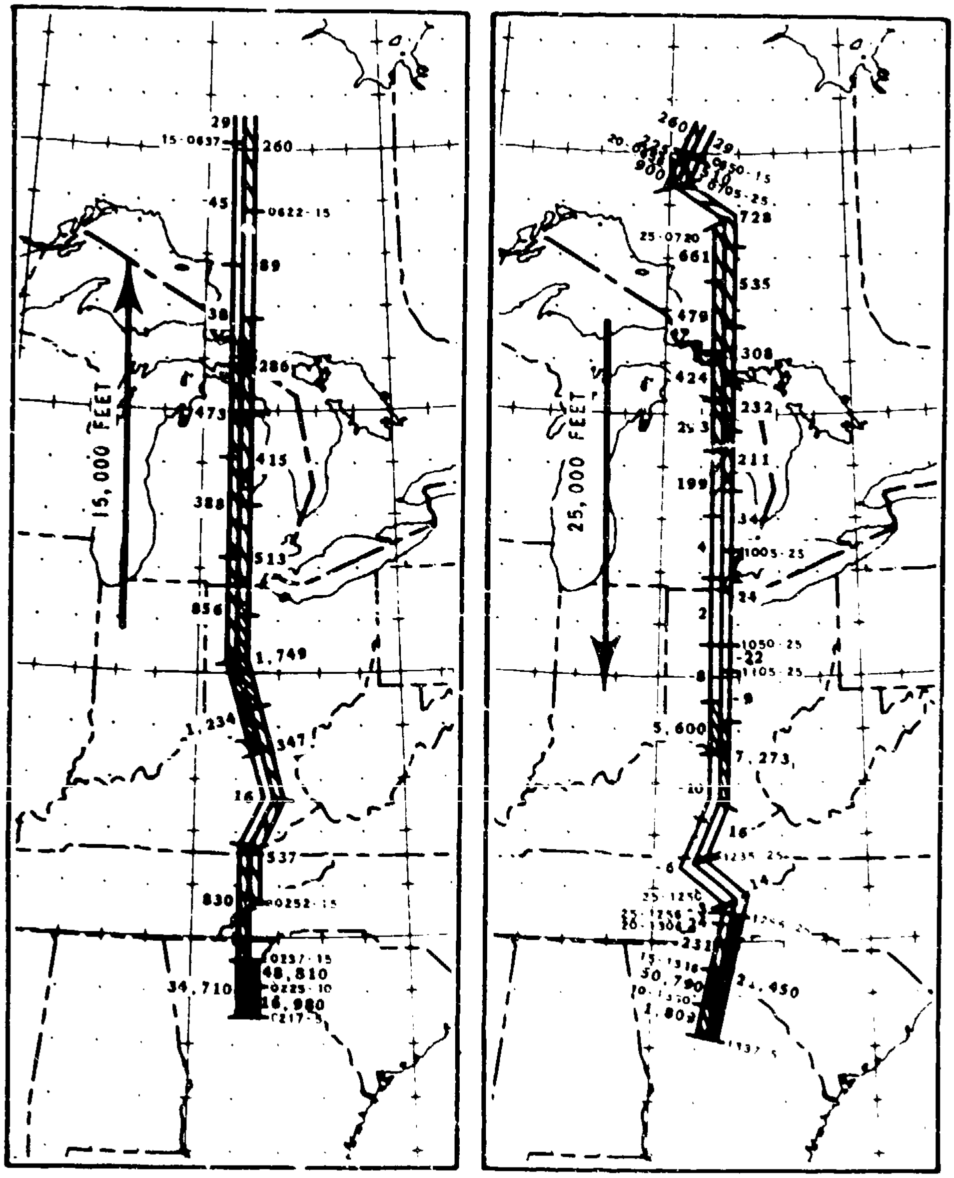


Fig. 3.19 LARK WILLIAM 5, 2 November 1951

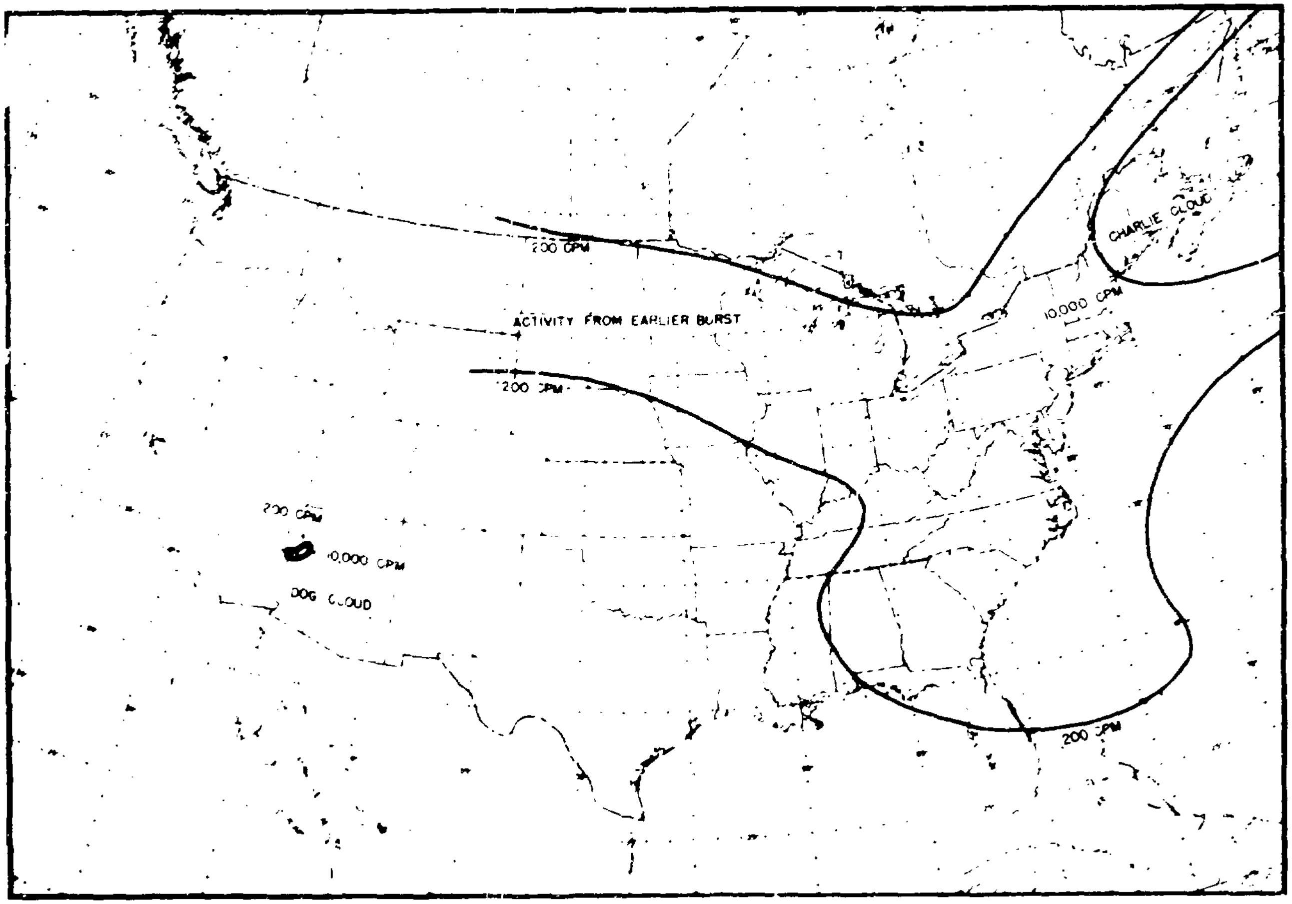


Fig. 3.20 Areas of Radioactive Debris at 400 mb (24,000 Feet) at 1800 GMT 1 November 1951

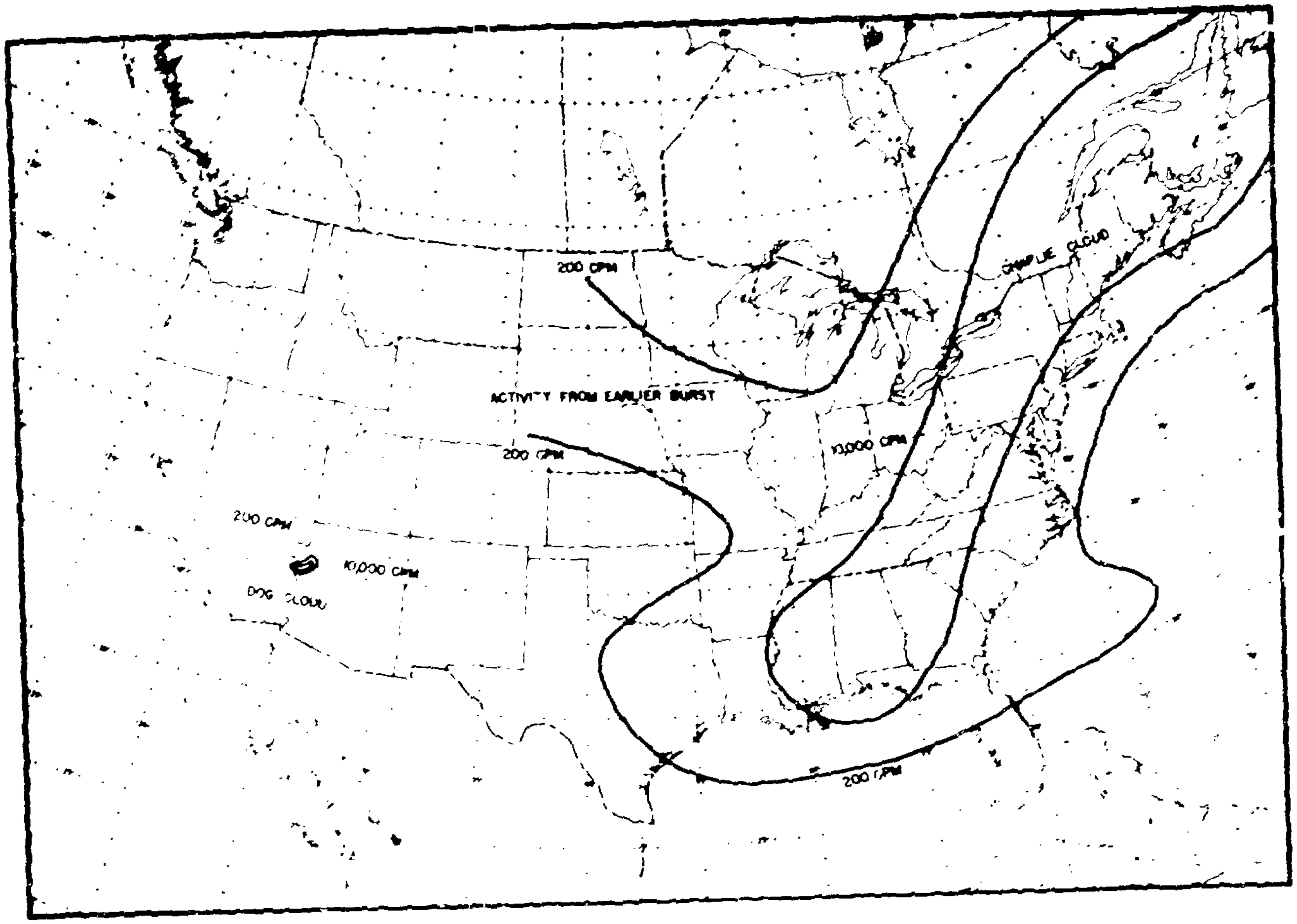
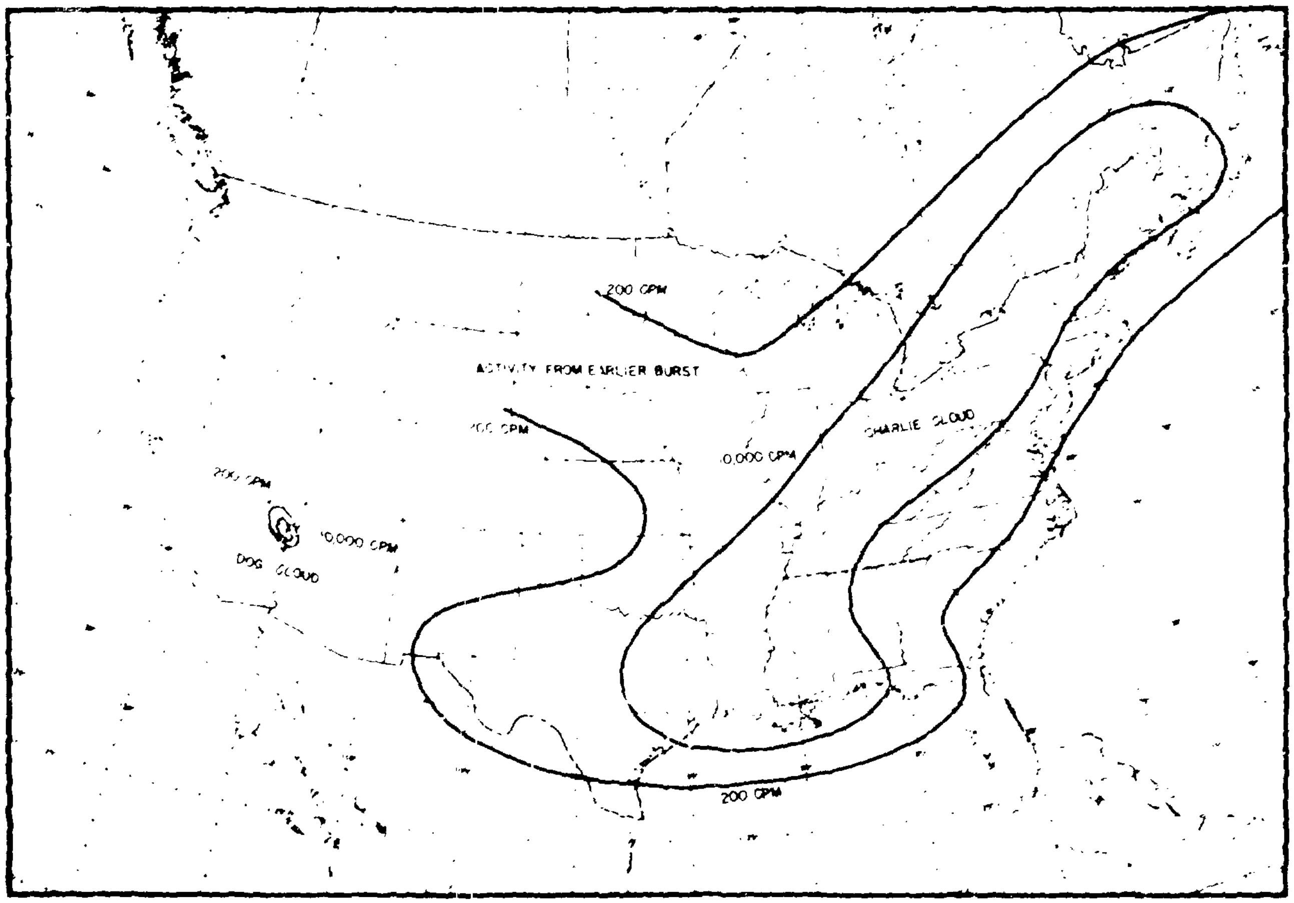


Fig. 3.21 Areas of Radioactive Debris at 500 mb (18,000 Feet) at 1200 GCT 1 November 1951

Fig. 3.21 Areas of Radioactive Debris at 500 mb (18,000 Feet) at 1200 GCT 1 November 1951

Fig. 2.21 Areas of Radioactive Debris at 500 mb (18,000 Feet) at 1200 GCT 1 November 1951



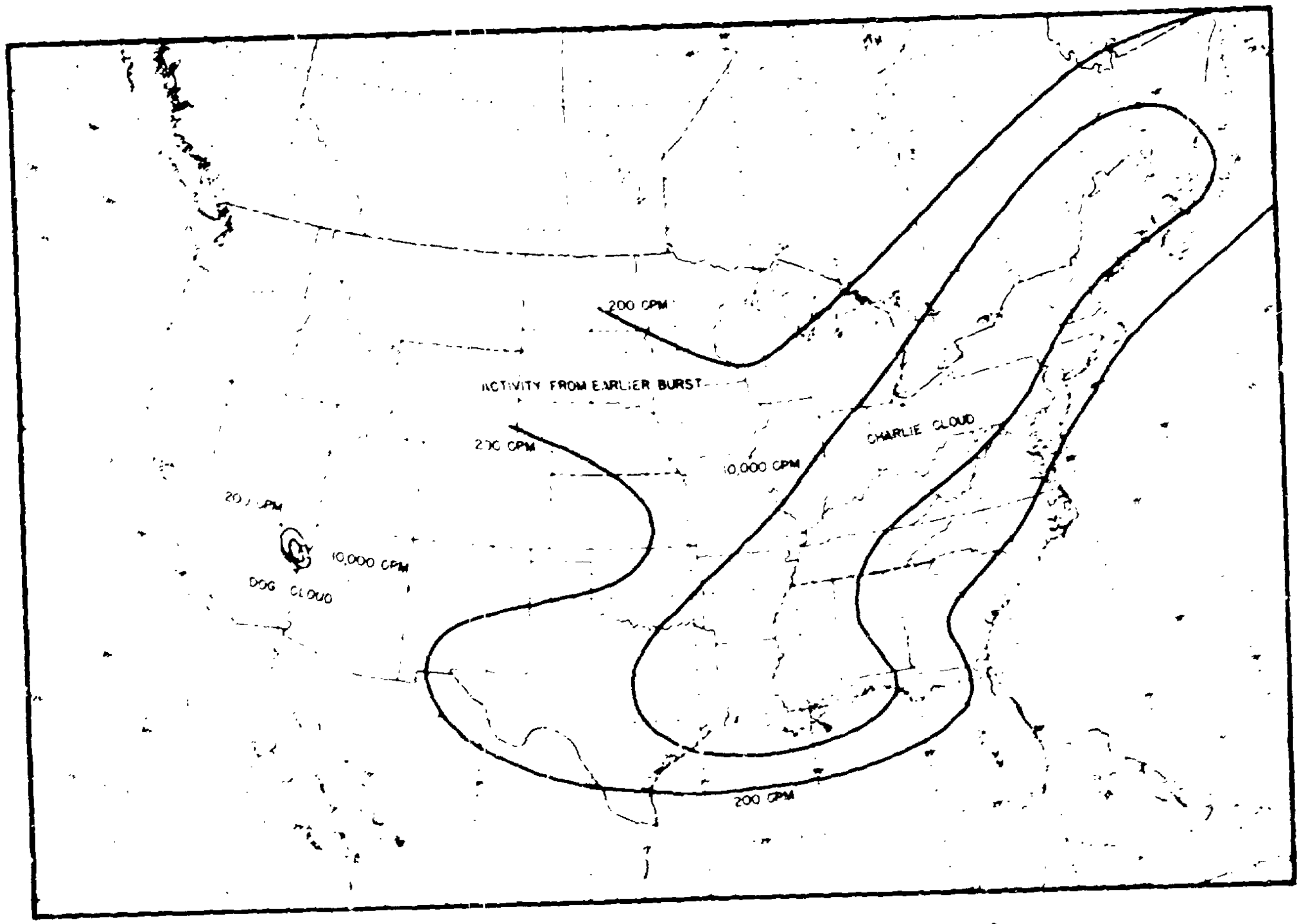


Fig. 2.22 Areas of Radioactive Debris at 700 mb (10,000 Feet) at 1800 GCT 1 November 1951

3.4 BUSTER DOG

Detonation of the fourth BUSTER weapon occurred at 1530 GCT 1 November 1951. The weapon was dropped from an airplane and exploded at 5600 feet msl (1400 feet above the ground).

3.4.1 Initial Cloud Dimensions

The cloud reached a maximum height of 46,000 feet with the base of the mushroom at 31,000 feet msl. A reddish-brown column, assumed to be largely bomb debris, was observed from 17,000 feet to the mushroom. The part of the cloud originally in the mushroom was rapidly stretched out by the wind shear through that layer, so that it was 12 nautical miles long 16 minutes after the explosion.

3.4.2 Initial Cloud Track

Analysis of the cloud position reports and of wind data over the area covered by the cloud made it possible to reconstruct the progression of the cloud at one-hour intervals for nine hours, as shown in Figure 3.23. The topmost part of the cloud moved southeastward and then eastward at an average speed of 75 knots, passing over Alamogordo, New Mexico, 7-1/2 hours after detonation. This portion was too high to be tracked by aircraft instruments, but the meteorological trajectory was quite well established. The portions at roughly 25,000 to 30,000 feet followed the same path but at slower speeds. The 15,000- to 20,000-foot layer moved southeastward and continued in that direction. The tracking aircraft remained at 20,000 feet and provided an outline of the cloud at that altitude. The northern (and higher) part of the column was widened by fallout from the mushroom, but the southern part was not enlarged except by the effects of directional shear and diffusion. The increase in diameter, measured front to back, may be considered due to diffusion alone, and represents a mean rate of growth of the diameter of about three knots.

3.4.3 Long-Range Cloud Path

Figure 3.24 shows the trajectories of the primary cloud at the indicated isobaric surfaces. It is seen that at the upper levels, 500 mb and above, the portions of the cloud moved along approximately the same path with high speeds, fanning out only after reaching the eastern part of the United States. The lower-level, slower part of the primary cloud, on the other hand, moved farther south and passed over the Gulf of Mexico.

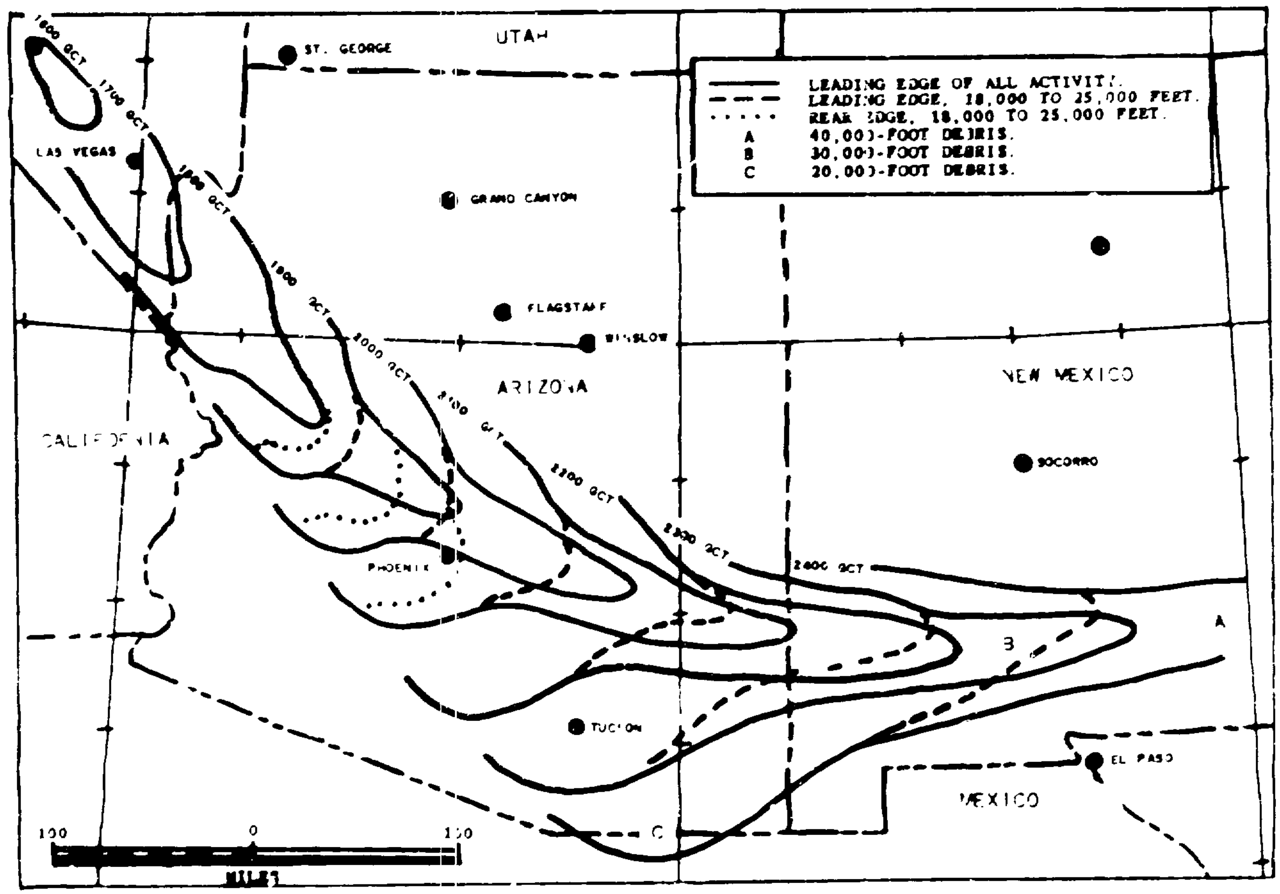


Fig. 3.23 Initial Movement of the BUSTER Dog Cloud. Detonation at 1530 GCT 1 November 1951; maximum height, 46,000 feet.

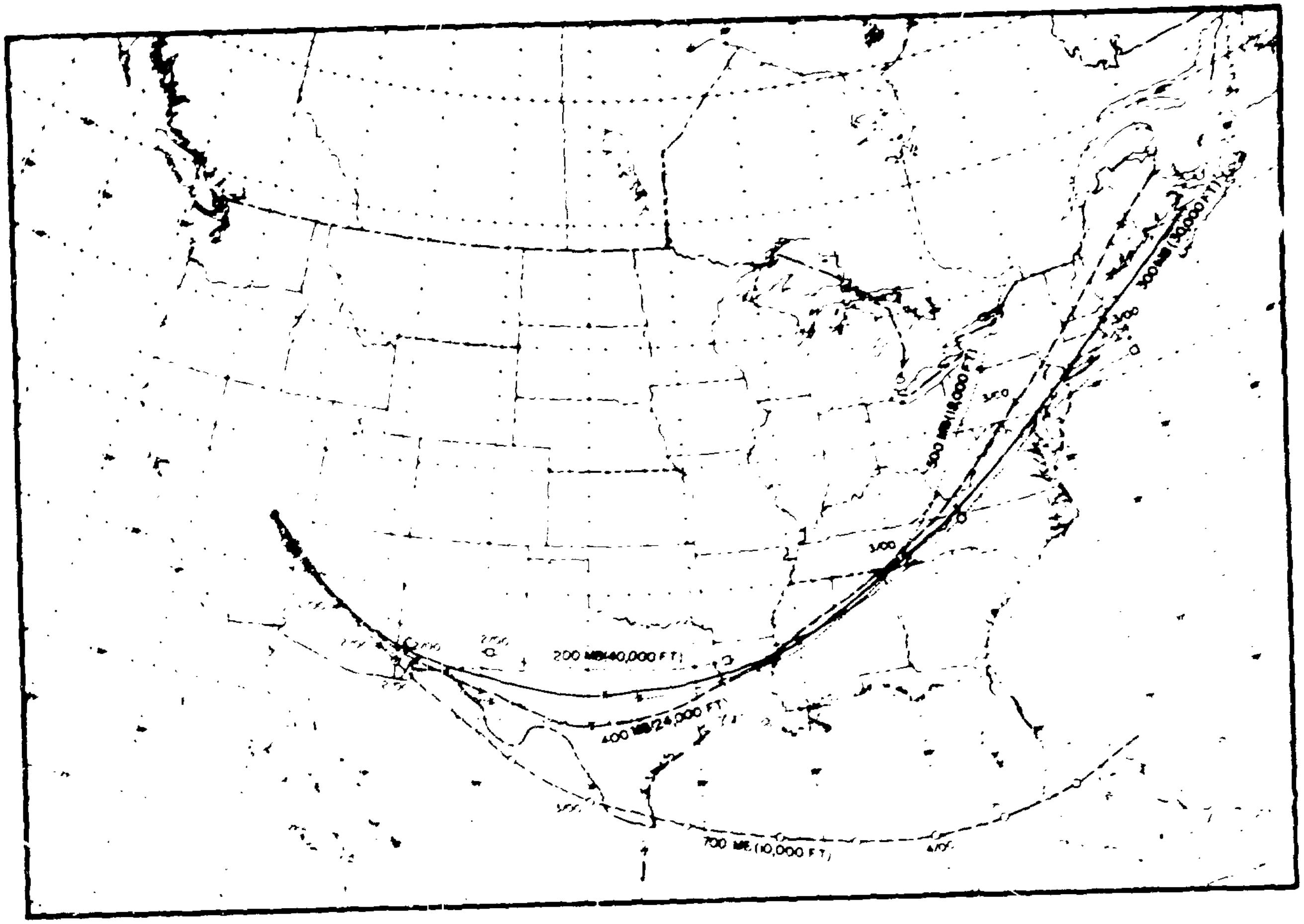


Fig. 3.24 Trajectories of the Primary Cloud from BUSTER Dog

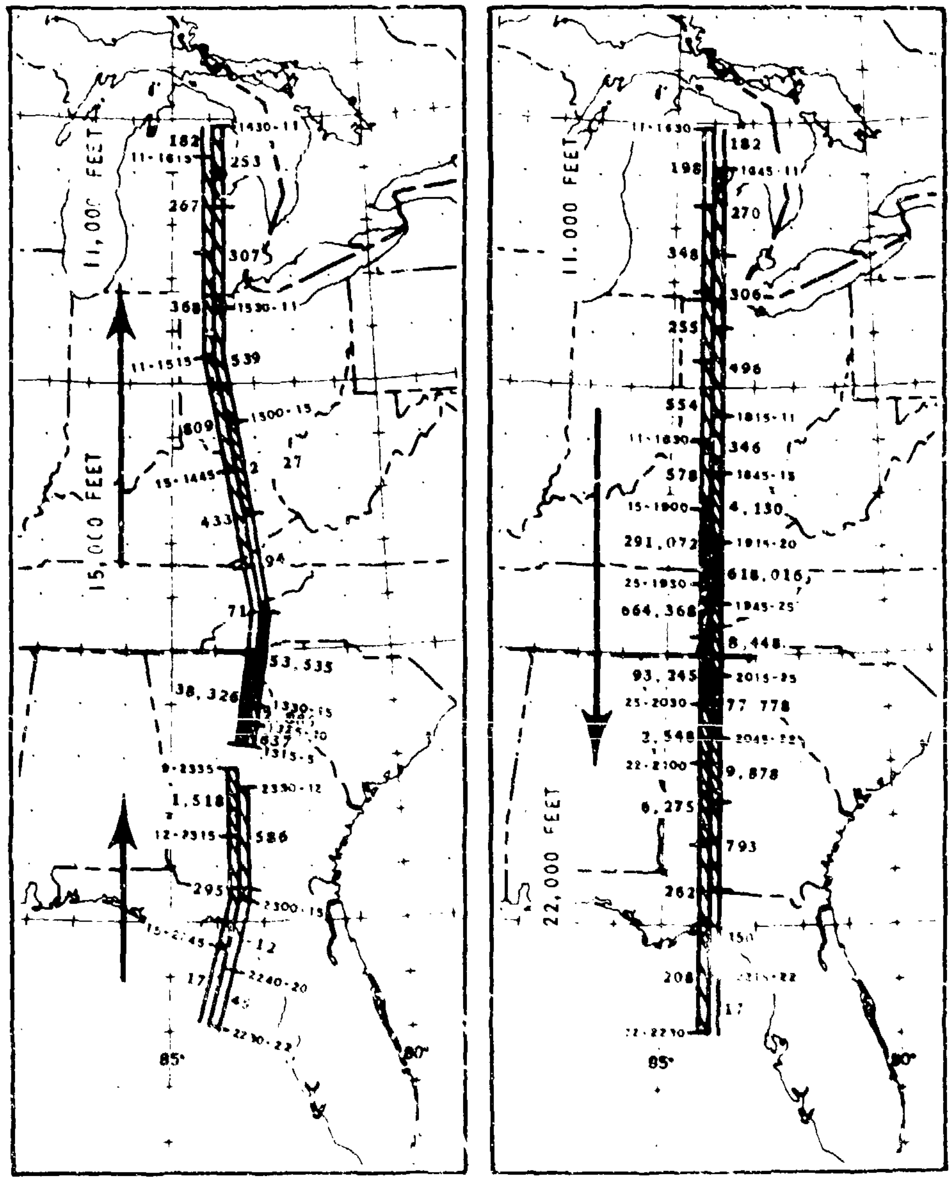


Fig. 3.25 LARK WILLIAM 6, 2 November 1951

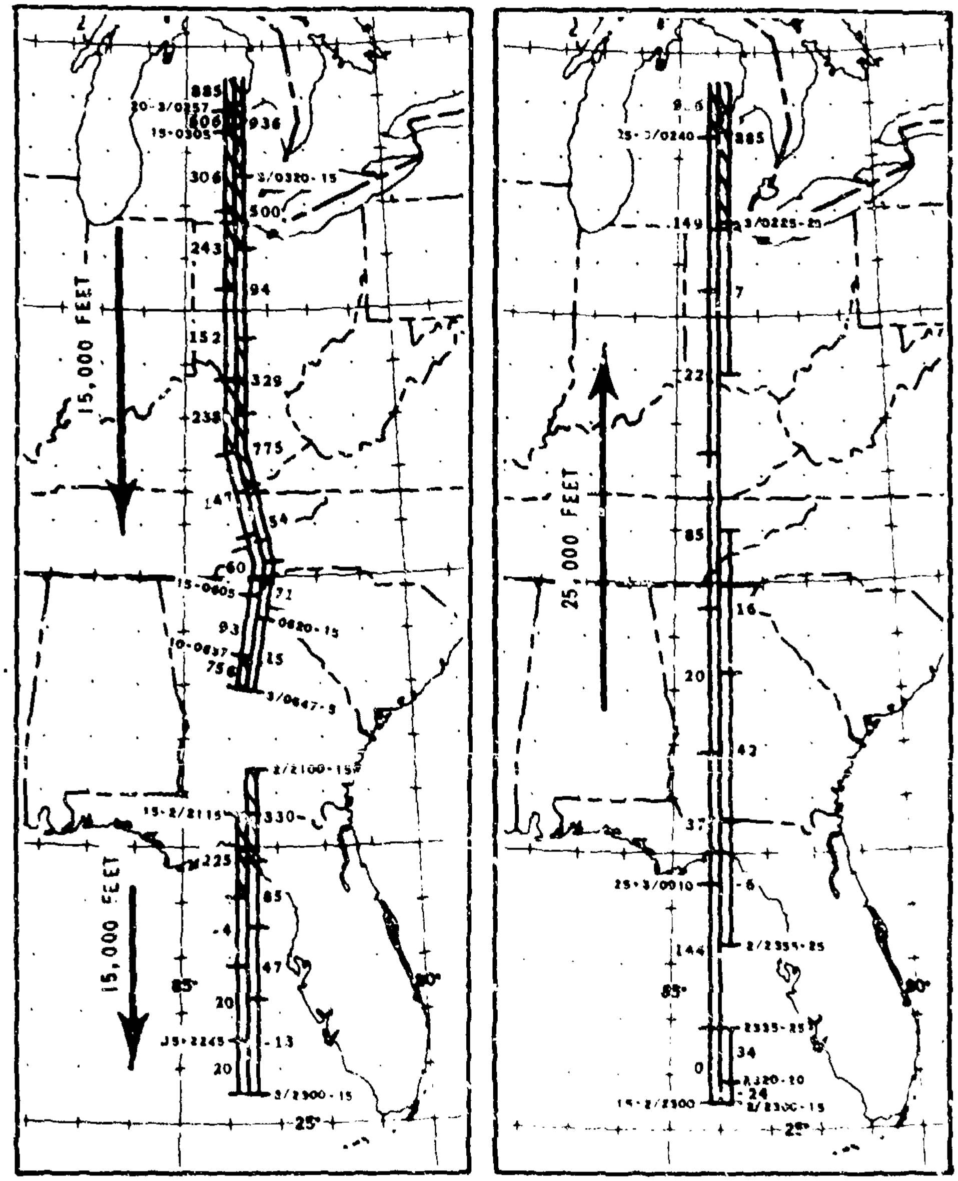


Fig. 3.26 LARK WILLIAM 7, 2-3 November 1951

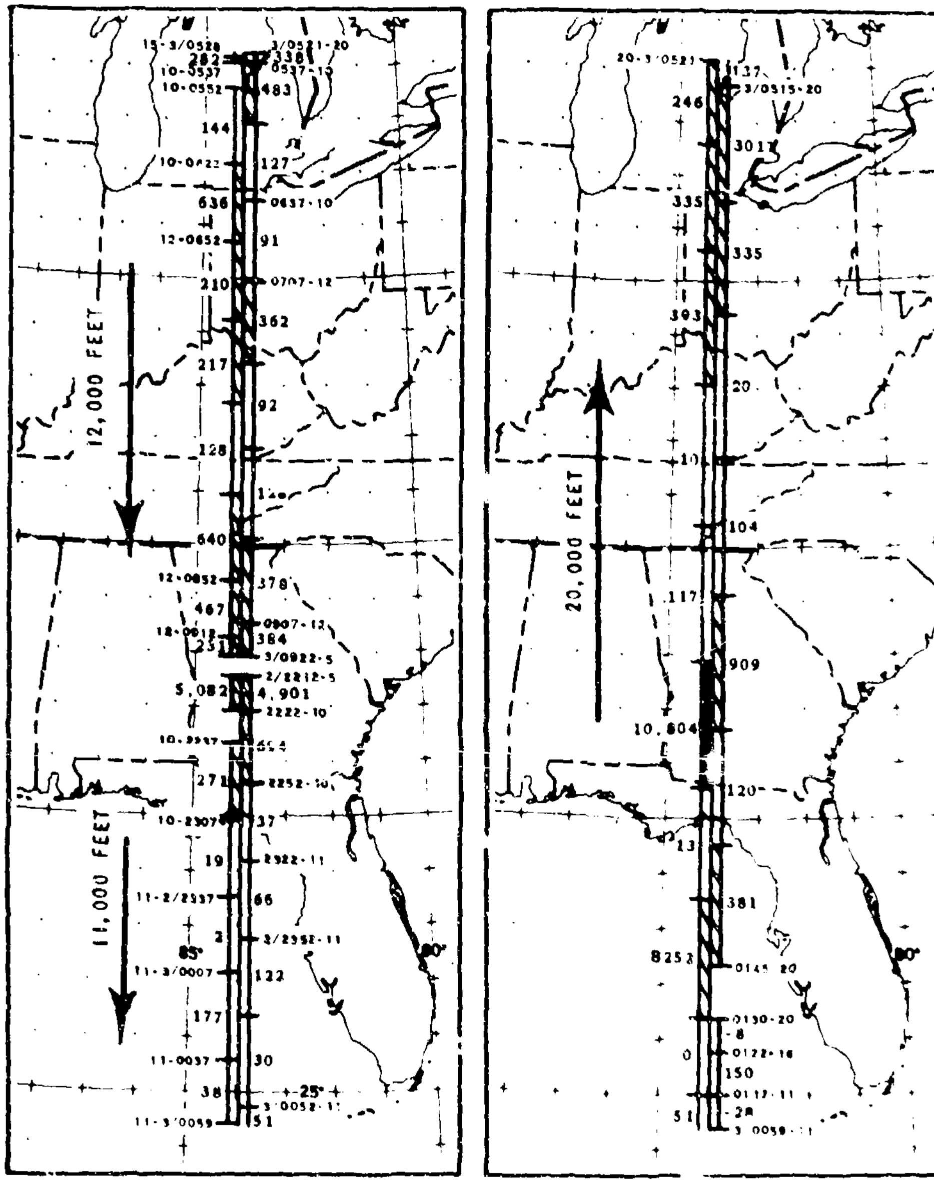


Fig. 3.27 LARK WILLIAM 8, 2-3 November 1951

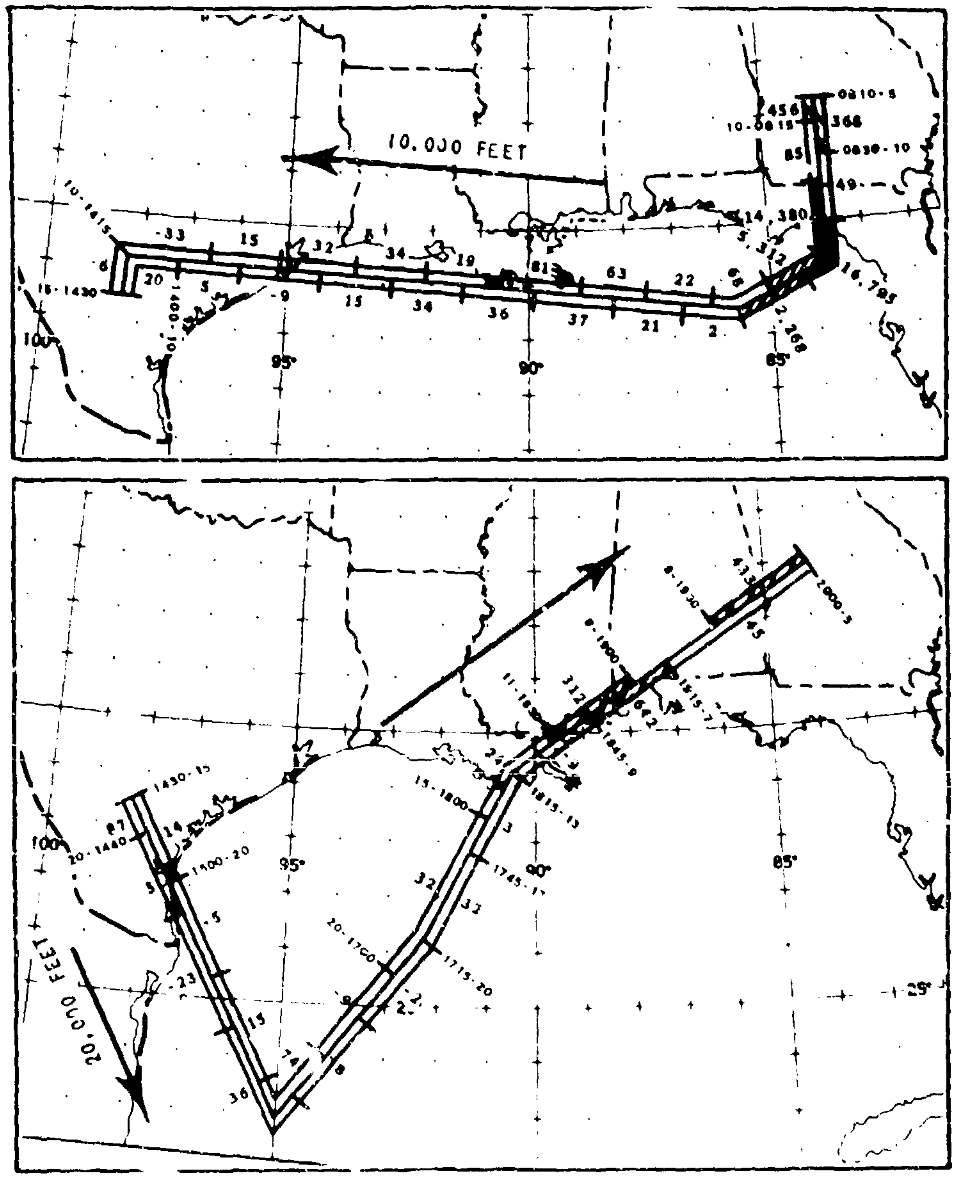


Fig. 3.28 LARK WILLIAM 9, 3 November 1951

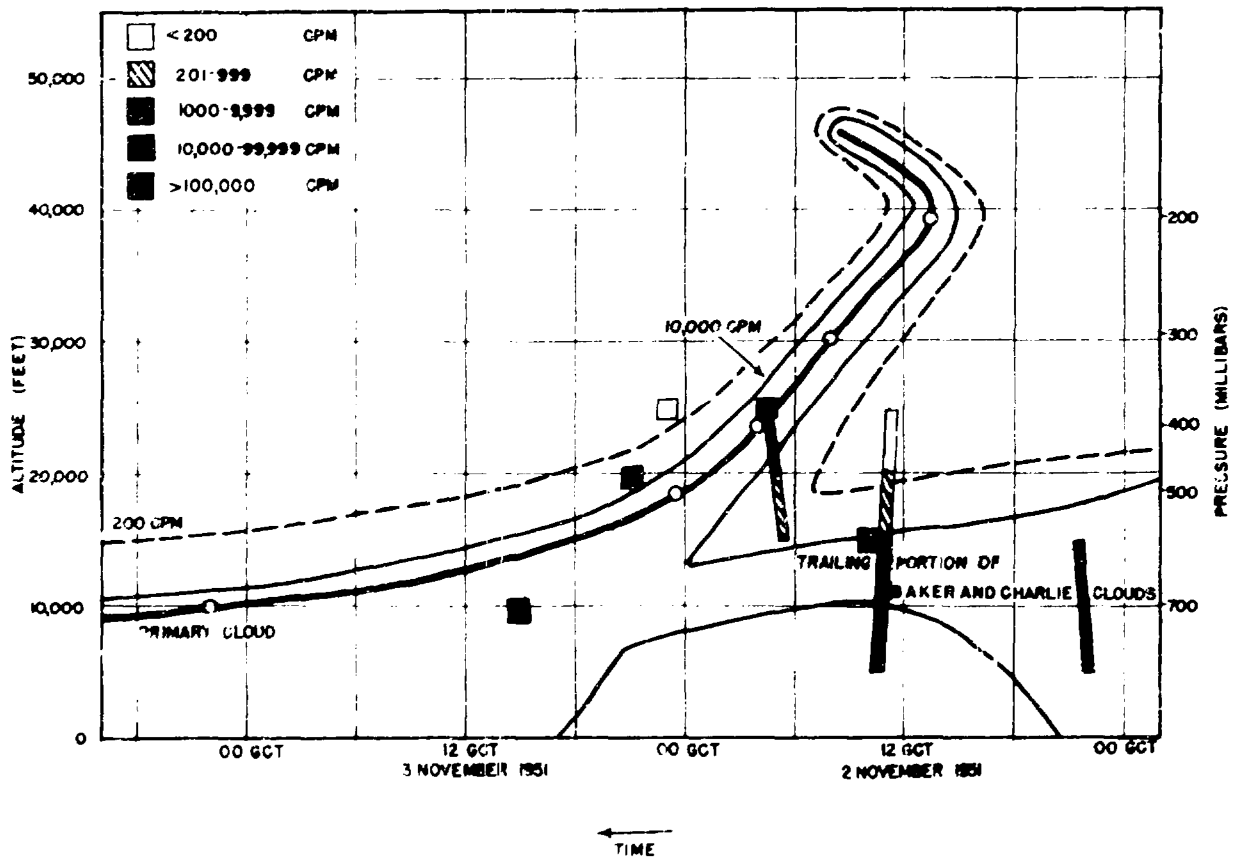


Fig. 3.29 Time-Altitude Cross Section at the 84th Meridian for Dog

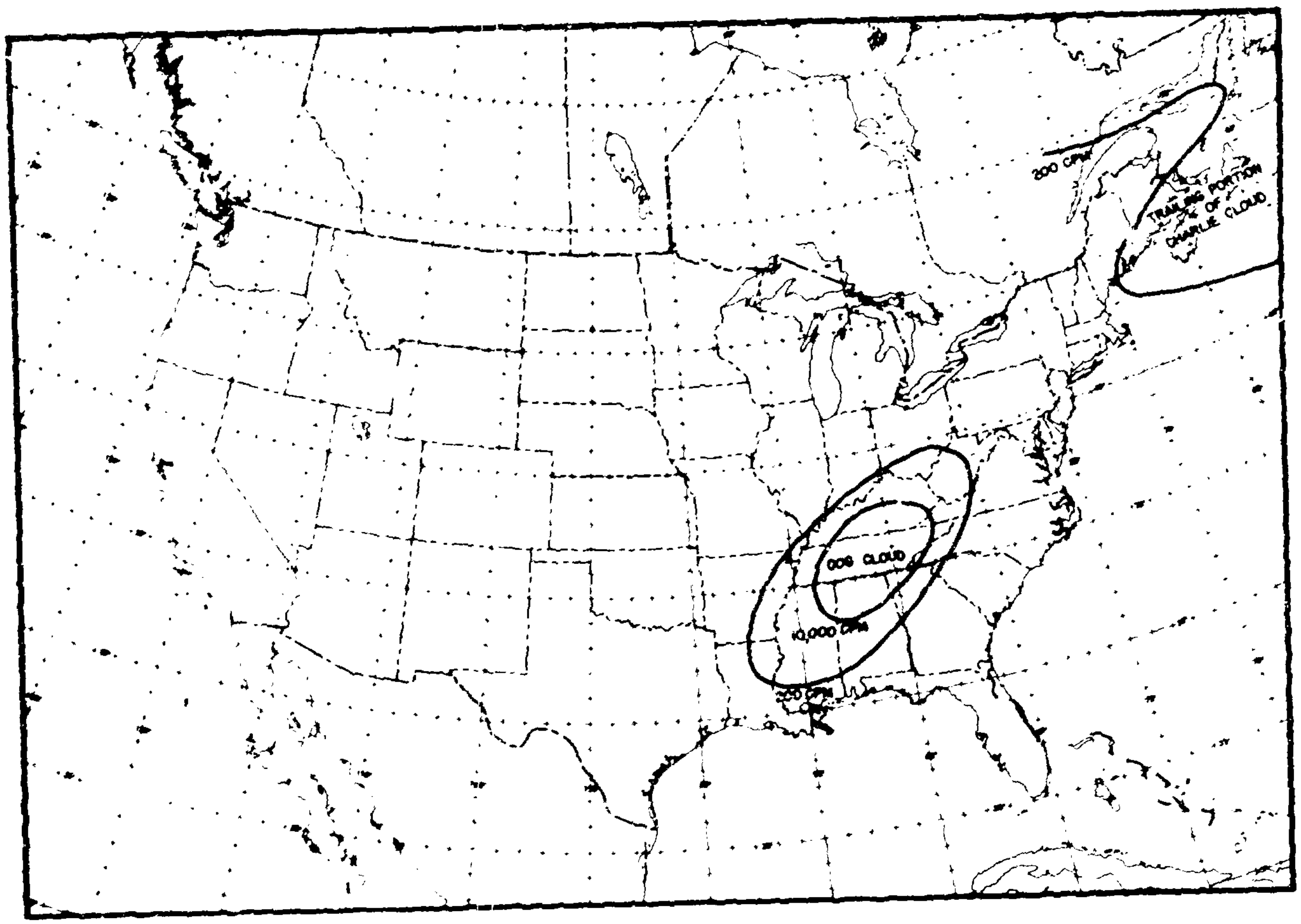


Fig. 3.30 Areas of Radioactive Debris at 400 mb (24,000 Feet) at 1800 GCT 2 November 1951

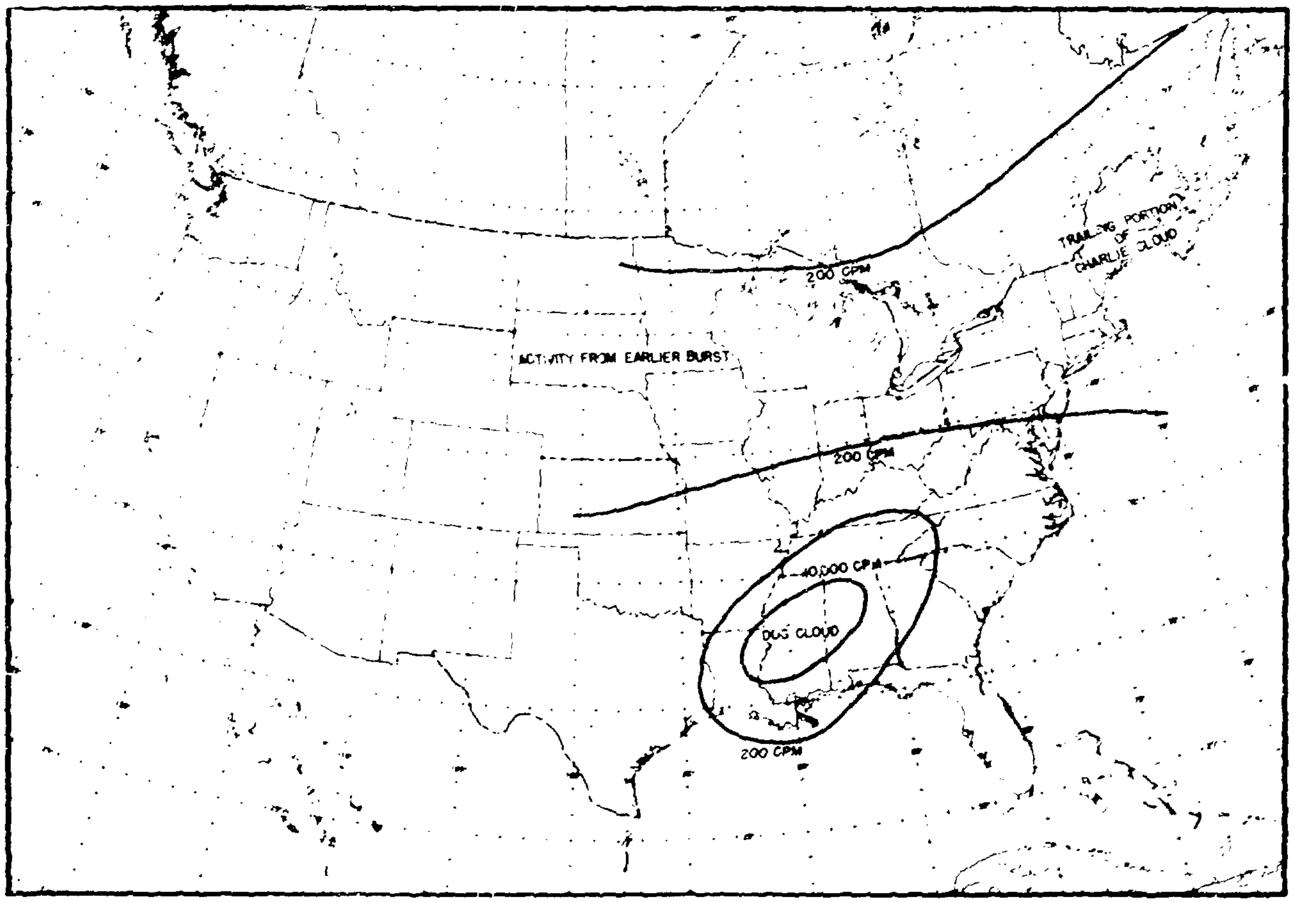


Fig. 3.31 Areas of Radioactive Debris at 500 mb (18,000 Feet) at 1800 GCT 2 November 1951

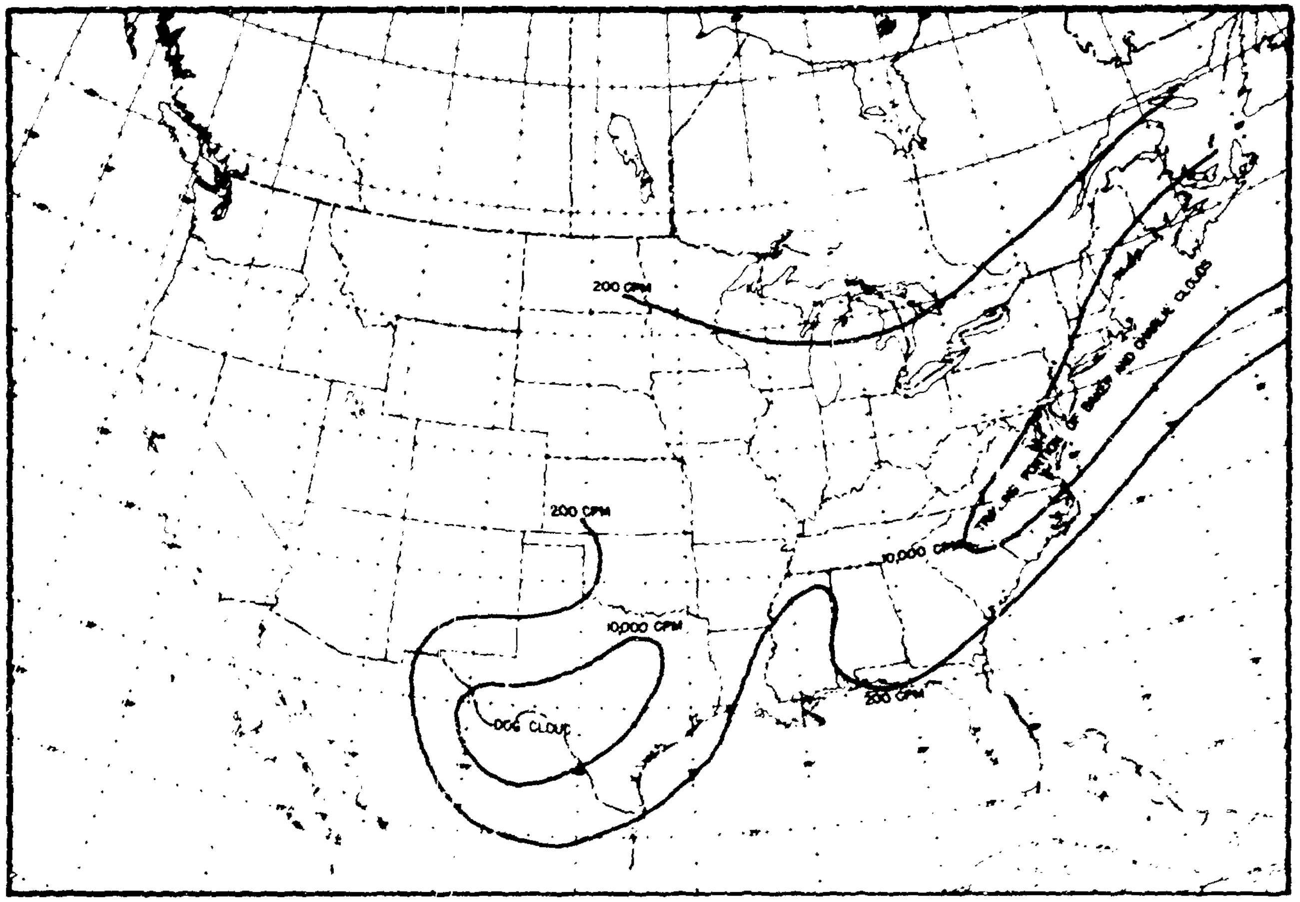


Fig. 3.32 Areas of Radioactive Debris at 700 mb (10,000 Feet) at 1800 GCT 2 November 1951

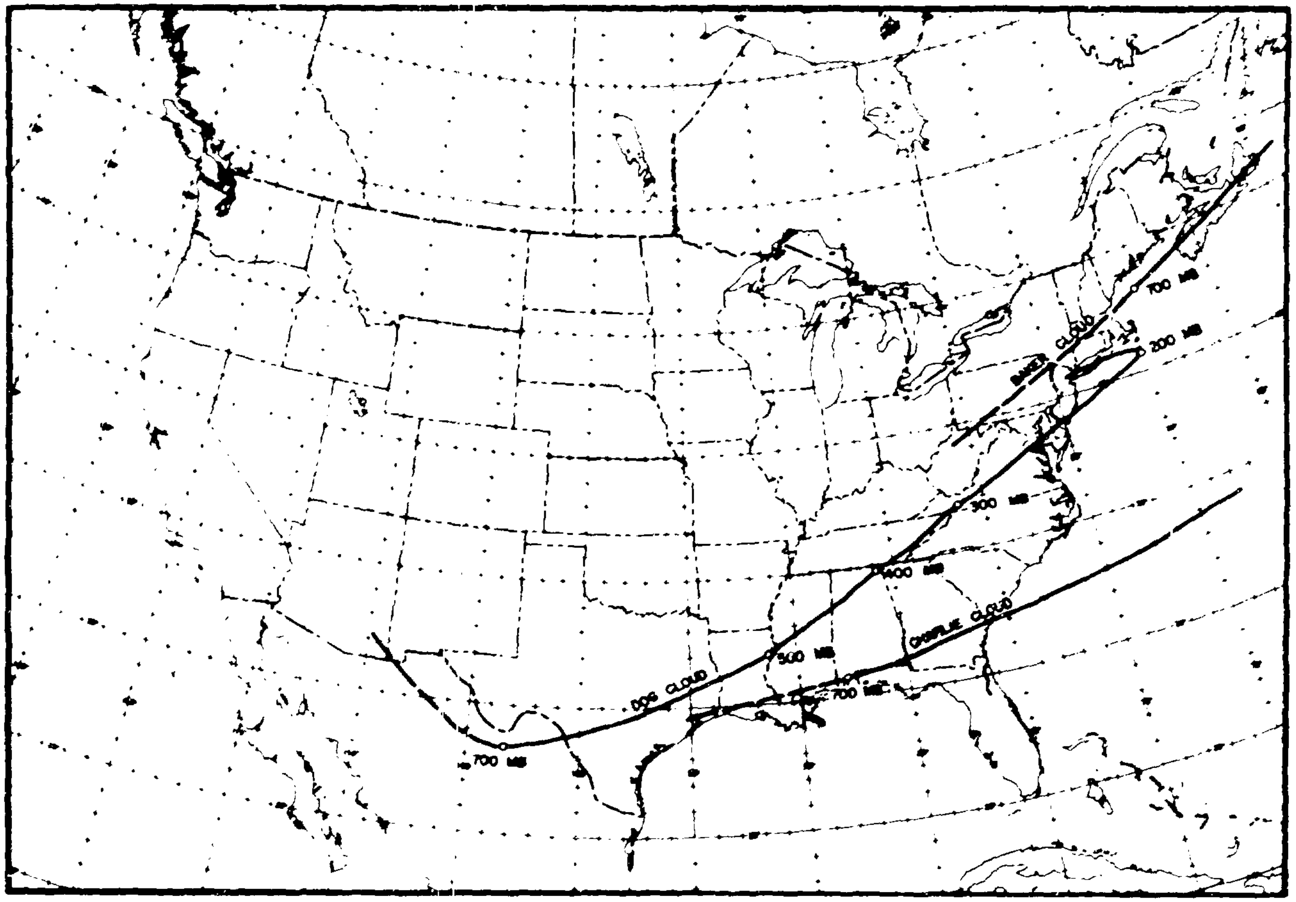


Fig. 3.33 Primary Clouds from Baker, Charlie, and Dog at 1800 GCT 2 November 1951

The concentrations of radioactive debris detected on the aircraft flights along the 84th meridian are shown in Figures 3.25 - 3.28. The high activity at 25,000 feet shown in Figure 3.25 can be positively associated with the Dog cloud.

Figure 3.29 is a time cross section for the Dog cloud of debris similar to Figure 3.11. It is seen that the duration of the passage of the debris at 20,000 feet and above is relatively short. This results, primarily, from the high speed and the directness of the movement of the upper portions of the cloud from the test area to the 84th meridian.

Figures 3.30, 3.31, and 3.32 outline the debris at 400 mb, 500 mb, and 700 mb, respectively. These figures, together with Figures 3.12-3.14 and 3.20-3.22, show the positions of the Baker, Charlie, and Dog clouds at the same three levels at 1800 GCT on three successive days. Of interest in the area delineations for the Dog cloud is the tilt of the core southwestward from 400 mb to 500 mb and the tremendous increase in the area of contamination as the elevation decreases. The presence of the debris from the Baker and Charlie clouds at 700 mb is also evident.

3.4.4 Distribution of Radioactive Debris at the Ground

Figure 3.33 shows the position of the primary clouds of the Baker, Charlie, and Dog debris at 1800 GCT 2 November 1952 as obtained from Figures 3.4, 3.16, and 3.24. The lower portion of each cloud (below 700 mb) could not be followed reliably by meteorological techniques but probably trailed off to the west as suggested by the dashed line. Diffusion and fallout must have extended the area covered by each cloud in the lower levels a considerable distance on each side of the core. This figure, together with Figures 3.29 and 3.32, shows that it is difficult, if not impossible, to distinguish the Baker, Charlie, and Dog debris at levels below about 10,000 feet over much of the southern and eastern United States. It is thus apparent that most of the radioactivity measured at the ground during this period (about 1-4 November) cannot reliably be attributed to a particular burst.

3.5 BUSTER EASY

The detonation of the atomic weapon for BUSTER Easy occurred at 1630 GCT, 5 November 1951. It was exploded at about 5500 feet msl (1300 feet above the ground).

3.5.1 Initial Cloud Dimensions

A theodolite located at Nellis Air Force Base for observation of this cloud provided a reliable report of 50,000 feet for the maximum cloud altitude. The cloud reached this elevation 12 minutes after burst time and was very nearly over the Control Point by the time it stopped rising. An almost complete separation of the mushroom from the stem occurred, with the base of the mushroom at about 35,000 feet and the top of the stem at about 20,000 feet. A tenuous dust veil connected the stem to the mushroom.

3.5.2 Initial Cloud Track

At the time of this explosion, north-northeasterly winds existed over the Test Site from the surface up to 12,000 feet, changing with altitude to northerly and northwesterly above 16,000 feet. The main portion of the bomb debris, the mushroom, moved south-southeastward, turning toward the east-southeast after 50 to 150 miles. The debris in the lower stem fanned out toward the south and southwest and was tracked for only four hours. The cloud outlines in Figure 3.34 are given at one-hour intervals for seven hours. The analysis is based on wind data and on radiological reconnaissance flights that intercepted no radioactive debris ahead of the estimated positions, thereby delineating the forward limit of the cloud.

Tracking airplanes were not able to fly high enough to sample the mushroom portion of the cloud, but they were able to follow the upper portion of the dust cloud and the fallout curtain from the high-level material. At about 2200 GCT one aircraft encircled a portion of the cloud at 18,000 feet. It was concluded, from the low activity encountered and from the position, that most of the particles in this cloud had fallen or diffused downward from the mushroom.

3.5.3 Long-Range Cloud Path

Figure 3.35 shows the meteorological trajectories in connection with this test. The debris below 20,000 feet curved clockwise over California before moving eastward. The path of this material is illustrated by the 700- and 500-mb trajectories. The path of the high-level material is illustrated by the 400, 300, 200 and 150-mb trajectories.

A great deal of the atmosphere over the United States north of 30°N was contaminated up to at least 25,000 feet by previous bursts. As a result, material that started from the Test Site below

20,000 feet became mixed with older debris. Therefore, the LARK WILLIAM flights that intercepted this material also intercepted the trailing material from earlier clouds, and it is not possible to distinguish the leading edge of the Easy cloud. The portion of the cloud that started eastward above 20,000 feet, however, remained south of the area of earlier contamination and was clearly delineated by the LARK WILLIAM flights from 7-11 November 1951 (Figures 3.36-3.43). Since the cloud that moved along the Gulf coast was initially above 20,000 feet, any material collected at lower altitudes was from the fallout curtain.

Figure 3.44 is a time cross section of the core of the Easy cloud as it passed the 84th meridian, constructed in the same manner as the time sections for the earlier clouds (Figures 3.11 and 3.29). The position of the debris intercepted at 25,000 feet on 1200 GCT and 1500 GCT, 7 November is in excellent agreement with the meteorological trajectory for this level, so it is probable that some of this material moved essentially at that level from the burst site. At the same time, a certain amount of this material moved vertically from adjacent levels but for two reasons the amount of material from other levels is believed to have been small.

First, experience with other test clouds indicates that the great length at any given level is due to debris moving at various altitudes (and therefore at different speeds) and subsequently moving to a common altitude. Had large amounts of debris from other levels moved to the 25,000-foot level, the cloud would probably have been much longer and could not have passed the 84th meridian in five to six hours.

Second, the earliest interception at 25,000 feet (Figure 3.37) showed no activity greater than 8000 cpm per half hour filter in spite of the fact that a high level of radioactivity can be produced by fallout alone (see, for example, the discussion of the BUSTER Charlie cloud in connection with Figure 3.21). This is consistent with the small amount of material that initially started eastward between 20,000 and 35,000 feet.

It will be noted that after the absence of debris at 25,000 feet at 1800 and 2200 GCT of the 7th, material was again intercepted after 0200 GCT of the 8th. This debris must have started at high elevations, but descended below 25,000 feet and traveled for a considerable period before being again carried aloft to the 25,000-foot level. Such a path must be assumed for this debris since no combination of the winds observed in the troposphere above 20,000 feet during the period of travel yields an average speed as low as that of this material. The slower wind speeds observed in the lower levels of the atmosphere would account for the delay in arrival at the 84th meridian. For this reason, we must conclude that debris collected at 25,000 feet early on the 8th was below 25,000 feet during the 7th. Large amounts of material, then, must have passed down through the 25,000-foot level, perhaps over Texas and New Mexico. Over the Gulf of Mexico vertical motions carried the material up to 25,000 feet where it was intercepted. This trailing cloud was wider than the cloud that was first intercepted, as would be expected from considerations of wind shear and eddy diffusion.

At the time the fallout curtain was intercepted at 10,000 feet (2000 GCT 7 November), there was sufficient directional shear in the winds below 20,000 feet to permit an estimate of the maximum time consumed in the vertical transport of this material. The LARK WILLIAM flights illustrated in Figures 3.37 and 3.38 indicate that the southern edge of the cloud at 10,000 feet was no more than 60 nautical miles south of the southern edge of the cloud at 25,000 feet. The velocity component from the north in the 15,000-foot layer under consideration was approximately 7 knots (averaged over either six hours or 12 hours), so it is probable that the material was below 25,000 feet a maximum of 10 to 12 hours before it was intercepted by the filter flights. This time requires a mean vertical transport of 21 to 25 feet/minute. It should be pointed out that this rough estimate gives a minimum rate of vertical transport. The data are not sufficiently accurate to estimate a maximum rate, nor is there any indication as to whether this vertical transport affected the bulk of the material or only a small percentage of the material.

At 15,000 feet the LARK WILLIAM flight 13 (Figure 3.39) intercepted debris of high activity at 25°N. Debris at 15,000 feet could have arrived at this low latitude at that time only by moving consistently down from 20,000 or 25,000 feet since burst time. This corresponds to a net vertical transport of less than three feet per minute.

Figures 3.45, 3.46 and 3.47 illustrate the distribution of radioactive debris at various altitudes and times. Figure 3.45 represents the Easy cloud at 25,000 feet as of 1800 GCT 7 November 1951, as well as some debris from earlier tests. It should again be emphasized that cloud areas extrapolated very far from the flight line must be regarded as crude approximations. The 25,000-foot areas shown in Figure 3.45 are a case in point. The uncontaminated area at 25,000 feet immediately west of the cloud, shown at 80°W., has been discussed in connection with the time cross section. As was mentioned, it appears reasonable that at 1800 GCT of the 7th the debris west of the 84th meridian was below 25,000 feet and for that reason Figure 3.45 shows only one area of debris from the Easy cloud, although it is possible the Easy cloud was at 25,000 feet over the Texas Gulf Coast.

The area of contamination northwest of the Easy cloud was evidently divided into two branches by a narrow jet of high winds. Wind speeds in the areas labelled "Activity from earlier burst" in Figure 3.45 were approximately 50 knots at that time, while in the uncontaminated strip wind speeds exceeded 100 knots.

Figure 3.46 shows the cloud shape at 700 mb as of 1800 GCT 7 November 1951. No doubt contamination from earlier bursts lay north of this cloud but no filter data are available to indicate if there was a definite separation from the Easy material as at upper levels. The small core of great activity shown at 90°W was discussed in connection with Figure 3.44. This 700-mb cloud was composed of debris that diffused laterally as it moved downward from higher levels.

Figure 3.47 represents the cloud at 25,000 feet as of 1800 GCT 8 November 1951. A dashed line representing the path of a constant-level balloon is also shown and is discussed below.

The paramount feature of this figure is the comparatively narrow cloud of material from the Easy burst, separated from the activity to the north. The path of the Easy cloud was nearly west to east for over 1000 miles while much of the residual debris located 30° to 35°N came from much higher latitudes. The confluence of these two streams of air is unmistakable because we have, fortuitously, independent tracers in these two currents. The Easy cloud marks the southern air current while a constant-level balloon floating at 30,000 feet marked the northern stream.* It had been launched at Minneapolis on the 7th and crossed the 84th meridian midway between the times of Figures 3.45 and 3.47.

The uncontaminated area between the Easy cloud and the material to the north, was the axis of the jet of high winds discussed in connection with Figure 3.45.

---

* This balloon flight was number 645, launched from the University of Minnesota airport on 1913 GCT 7 November 1951. This flight at 30,000 feet was one of the regular balloons in the General Mills program and had no actual connection with the BUSTER tests. This trajectory is included on this figure because it is a verified flight path (aircraft-tracked) that is representative of part of the debris from earlier tests.

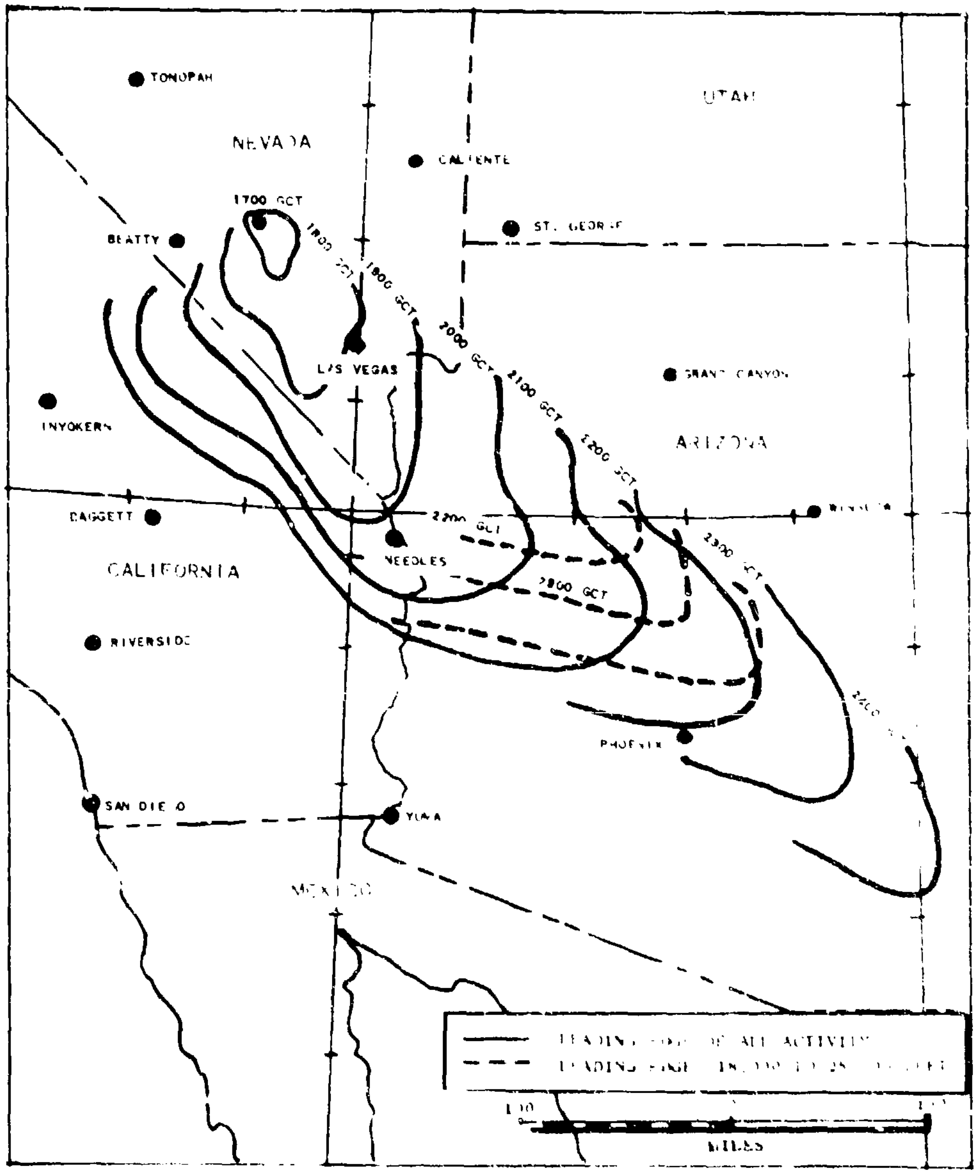


Fig. 3. 4 Initial Movement of the BUSTER Easy Cloud. Detonation at 1630 GCT 5 November 1951; maximum height, 50,000 feet.

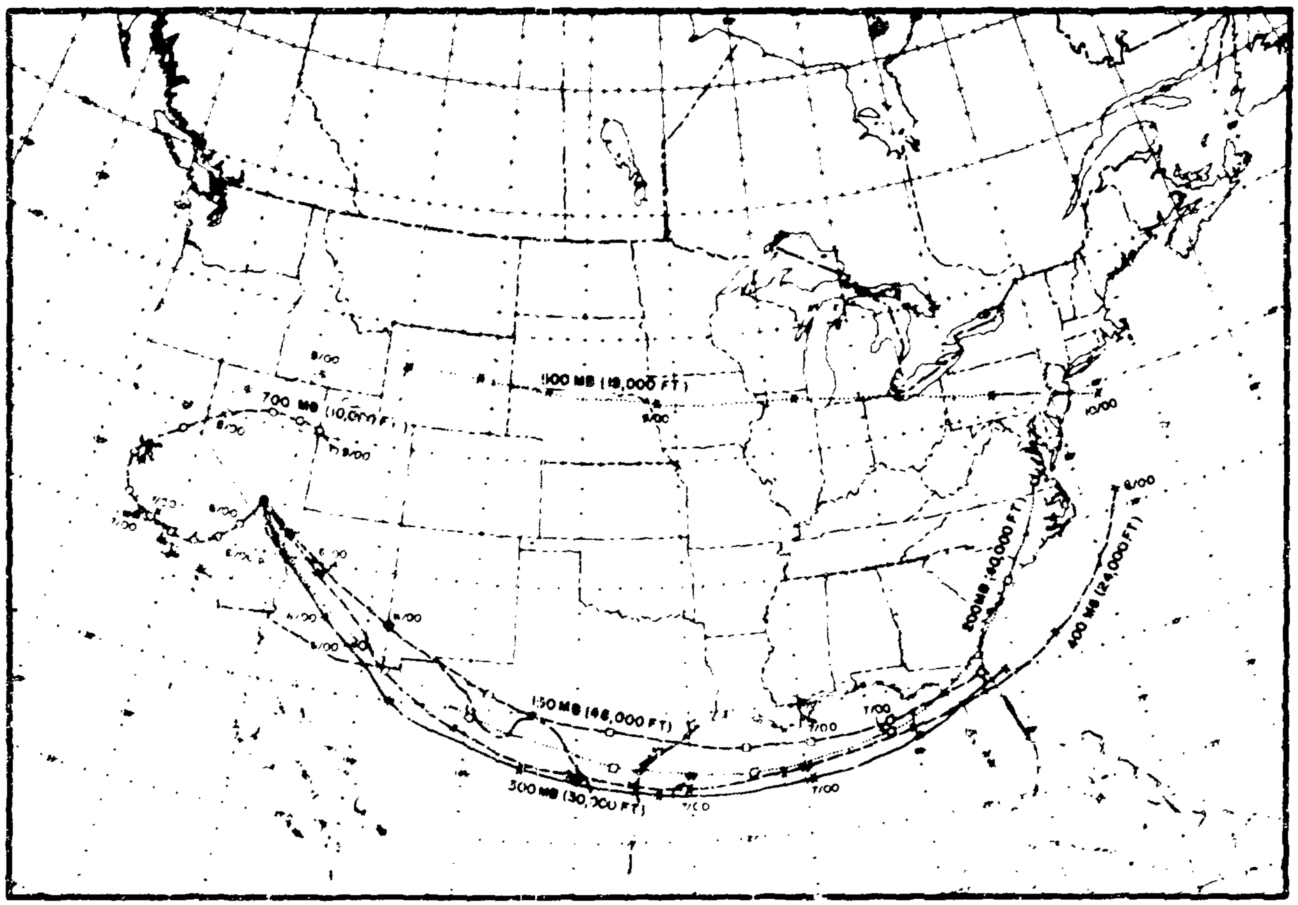


Fig. 3.35 Trajectories of the Primary Cloud from BUSTER Easy

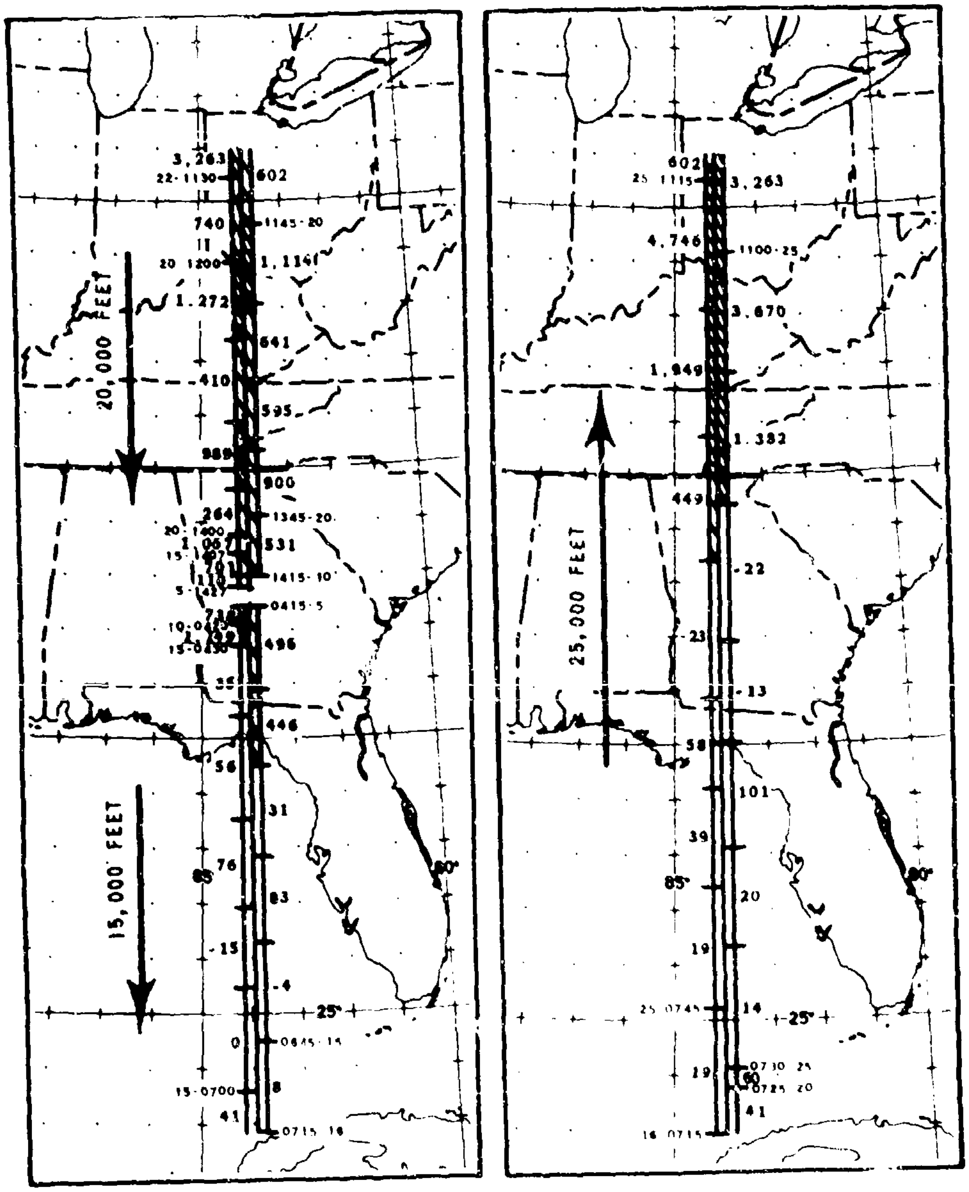


Fig. 3.36 LARK WILLIAM 10, 7 November 1951

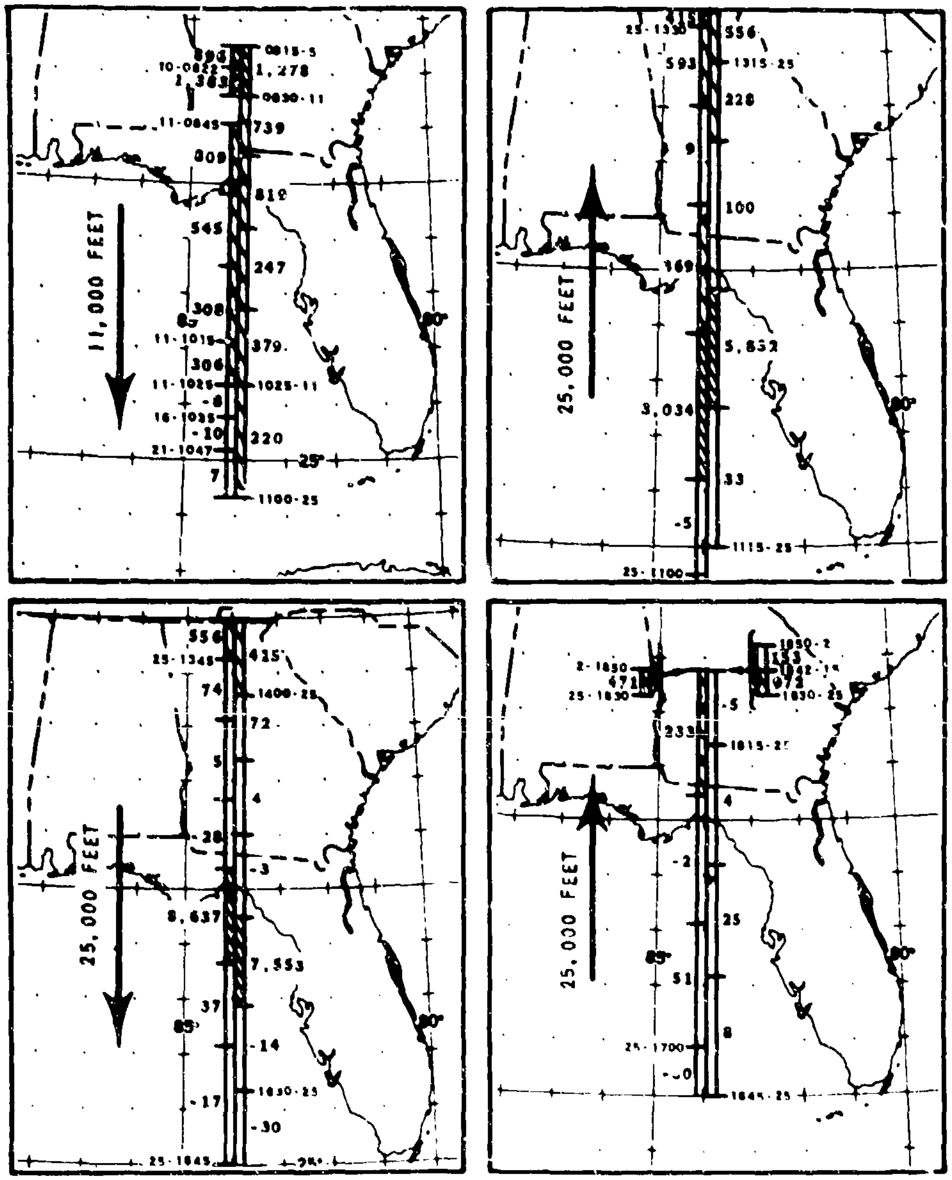


Fig. 3.37 LARK WILLIAM 11, 7 November 1951

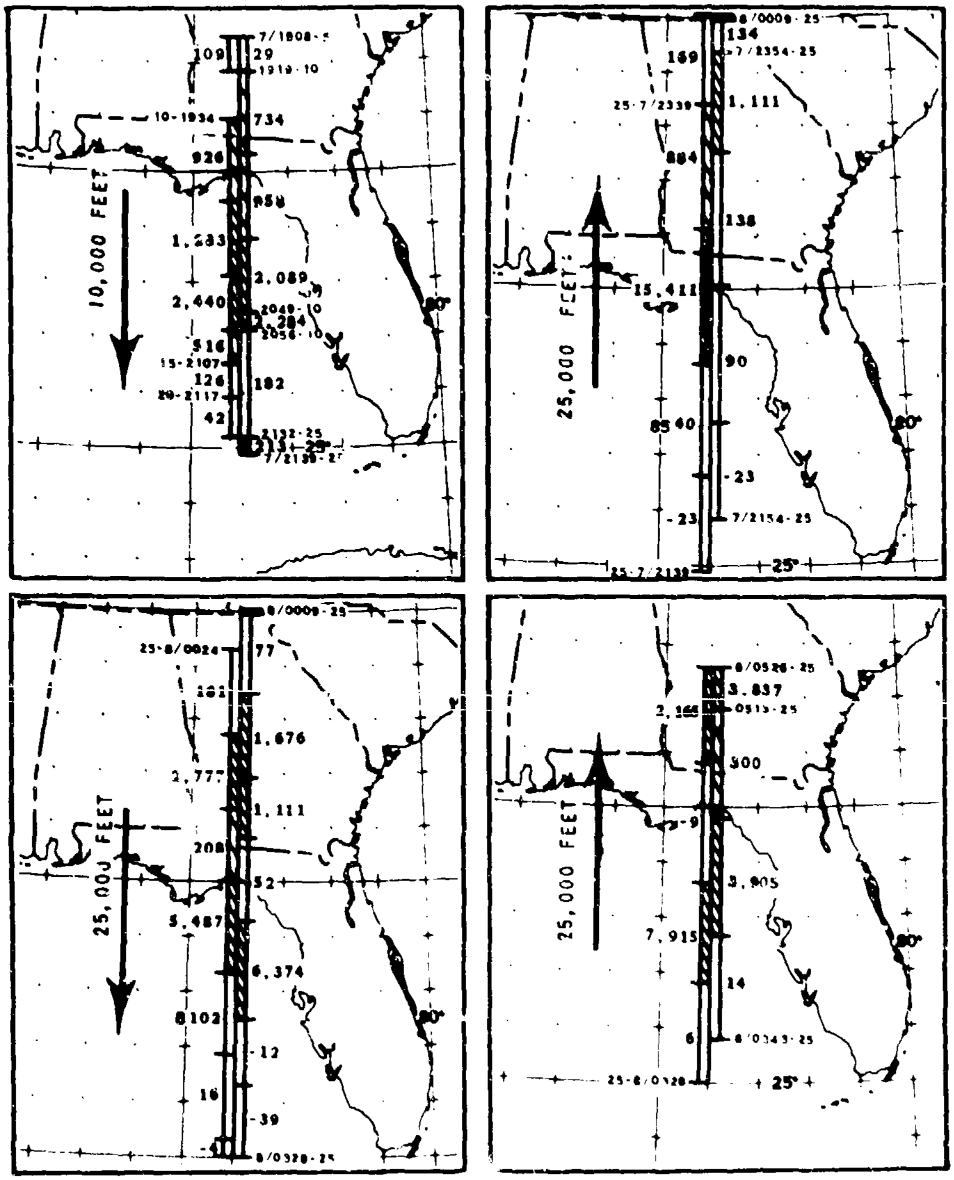


Fig. 3.38 LARK WILLIAM 12, 7-8 November 1951

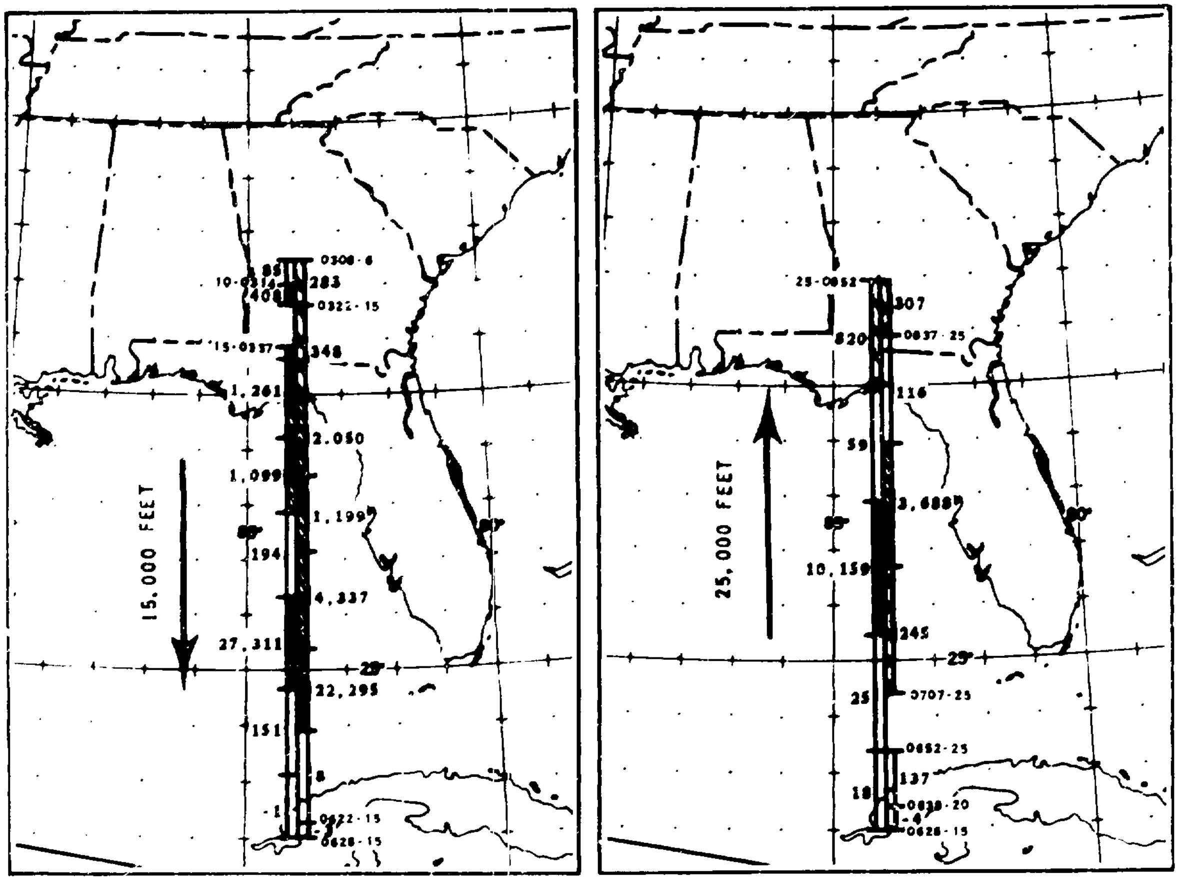


Fig. 3.39 LARK WILLIAM 13, 8 November 1951 - First Part

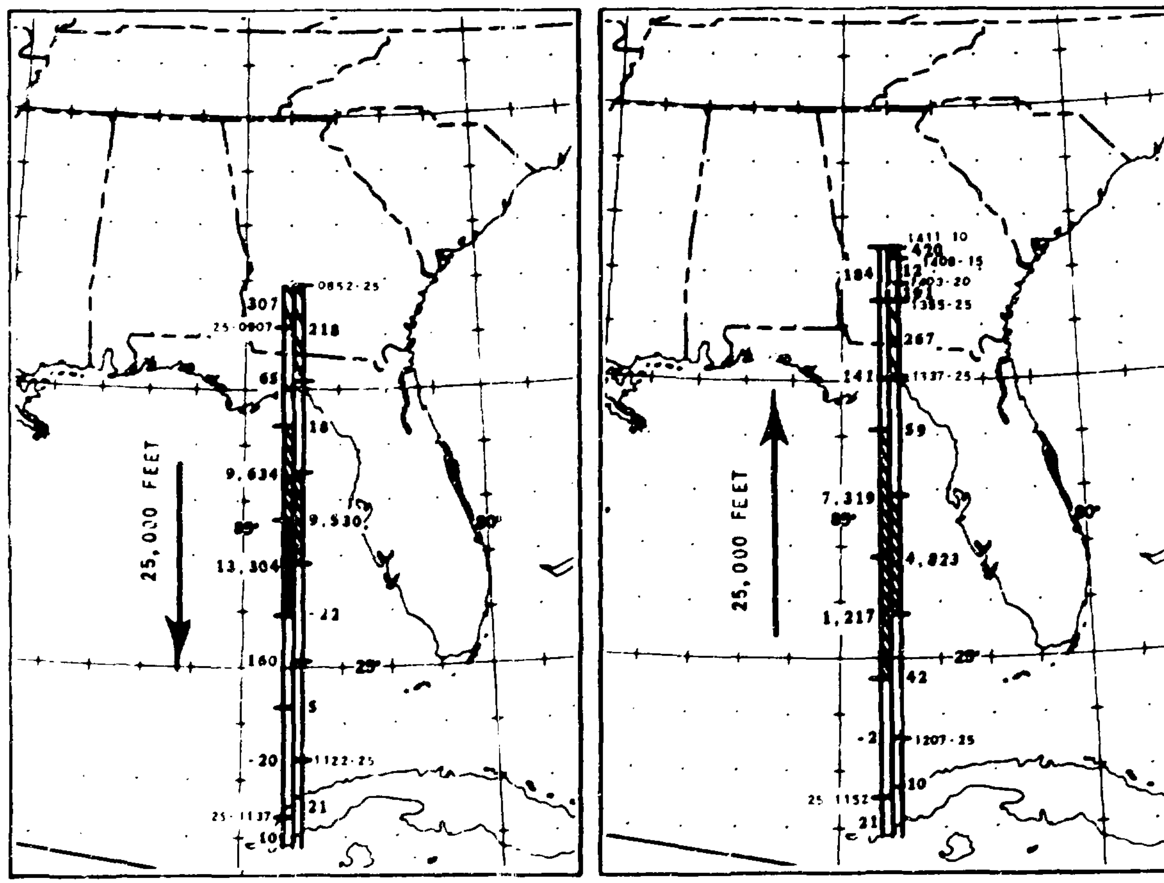


Fig. 3.40 LARK WILLIAM 13, 8 November 1951 - Second Part

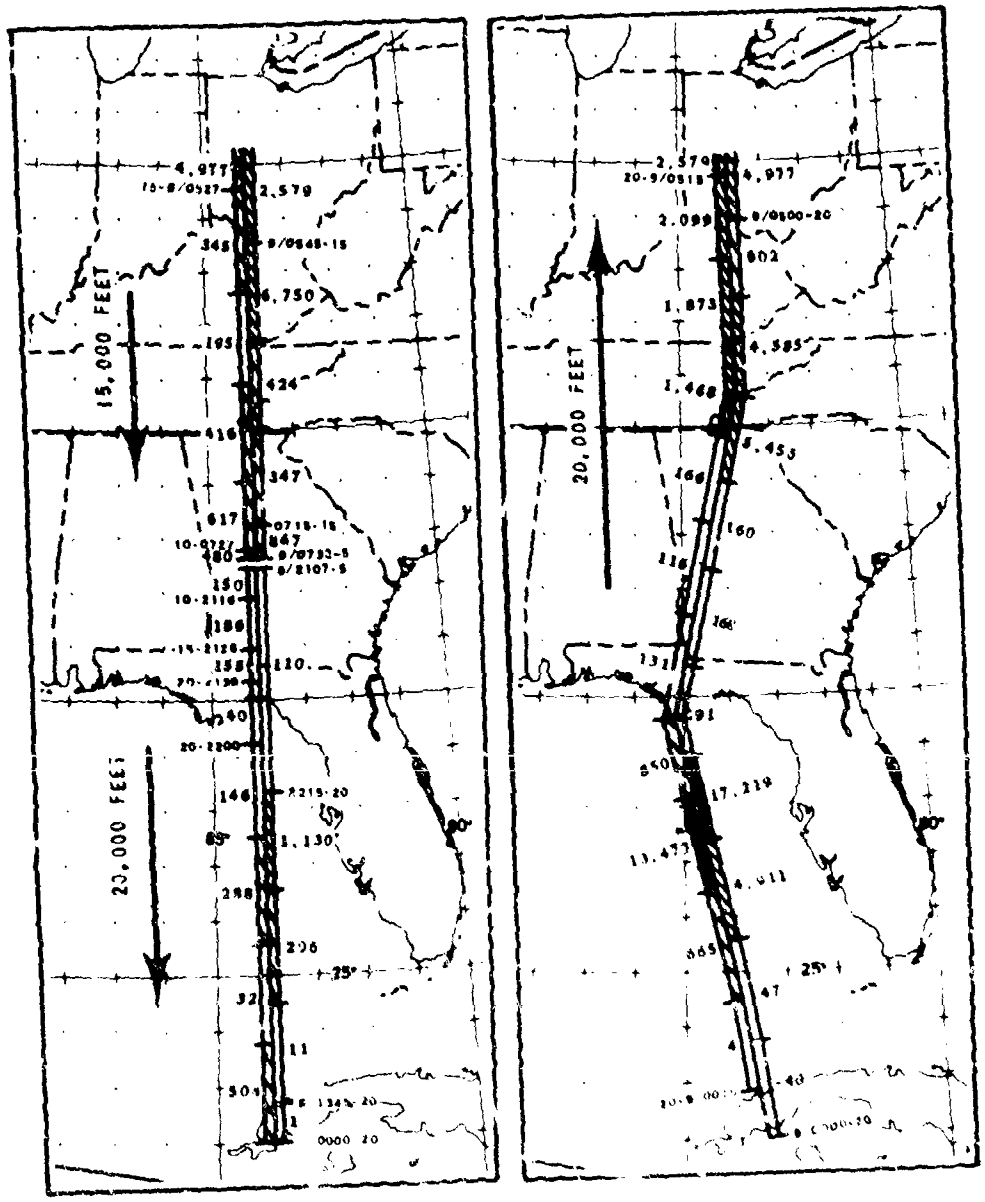


Fig. 3.41 LARK WILLIAM 14, 8-9 November 1951

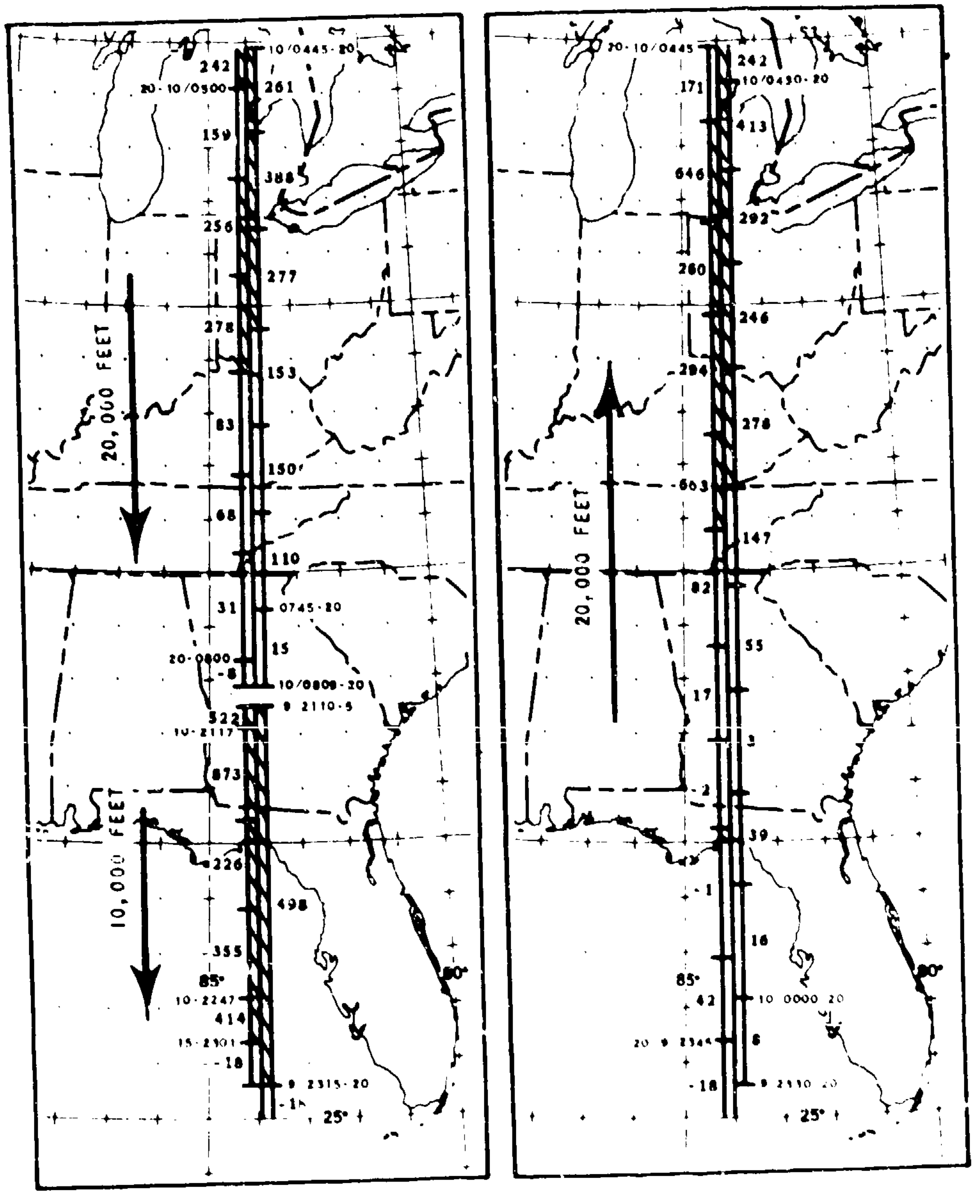


Fig. 3.42 LARK WILLIAM 15, 9-10 November 1951

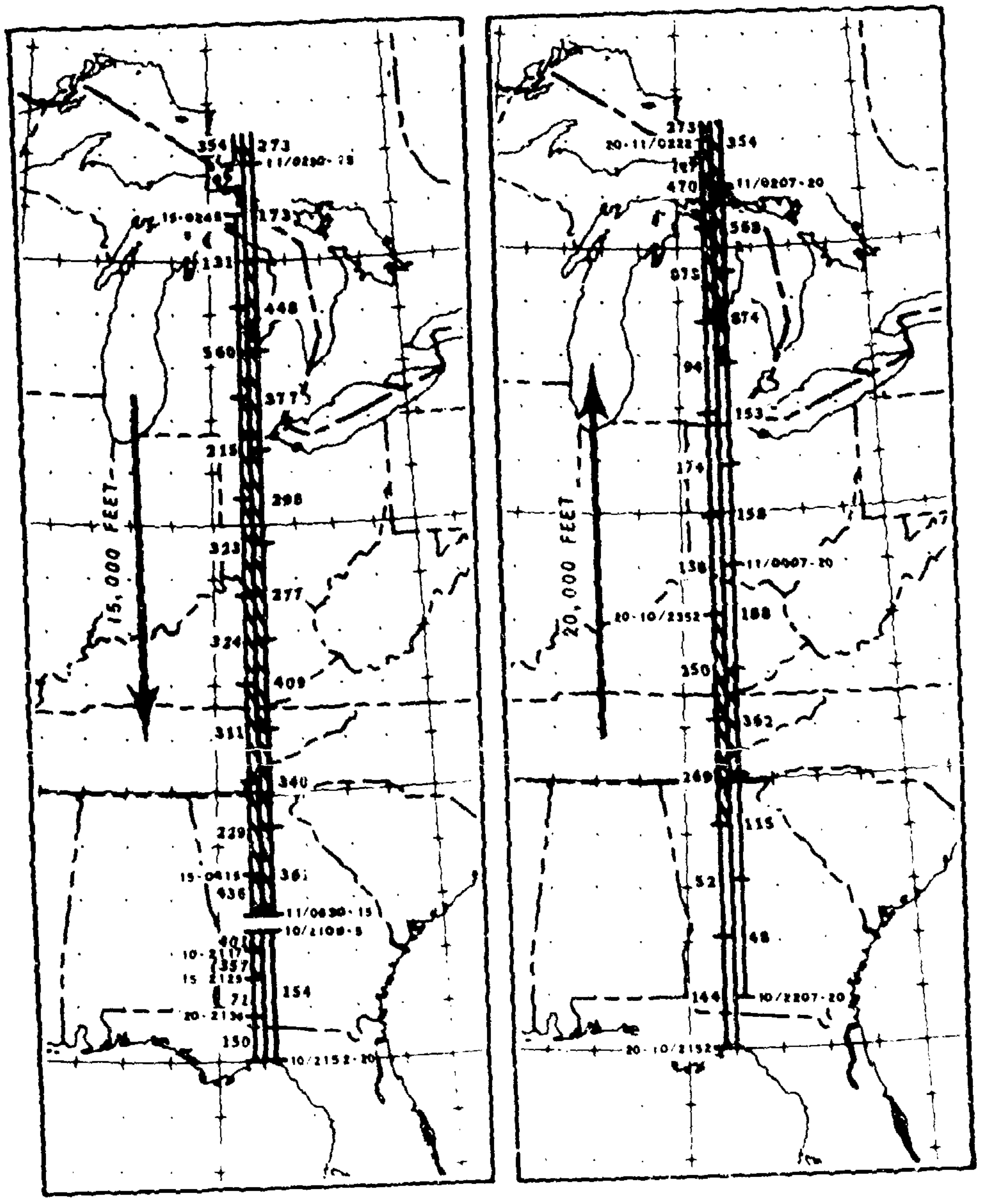


Fig. 3.43 LARK WILLIAM 16, 10-11 November 1951

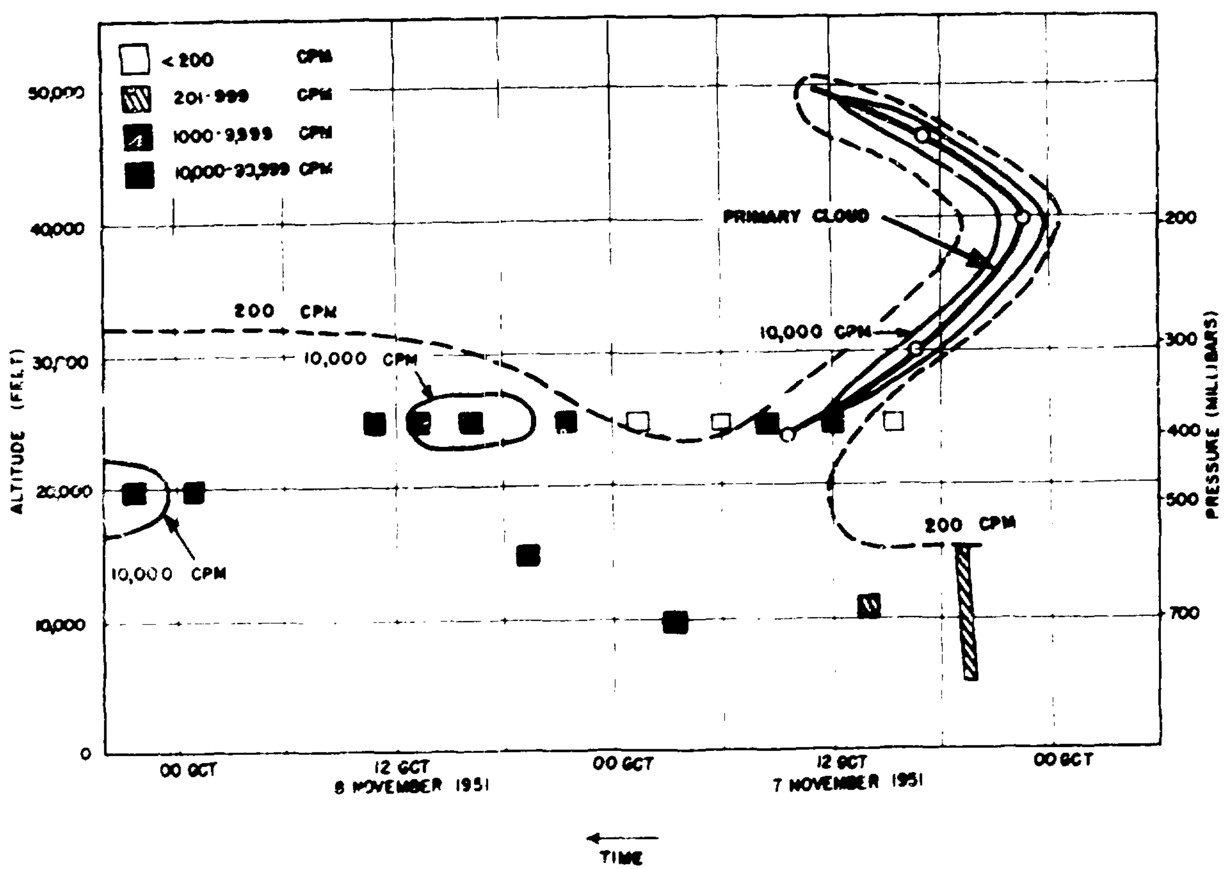


Fig. 3.44 Time-Altitude Cross Section at the 84th Meridian for Easy

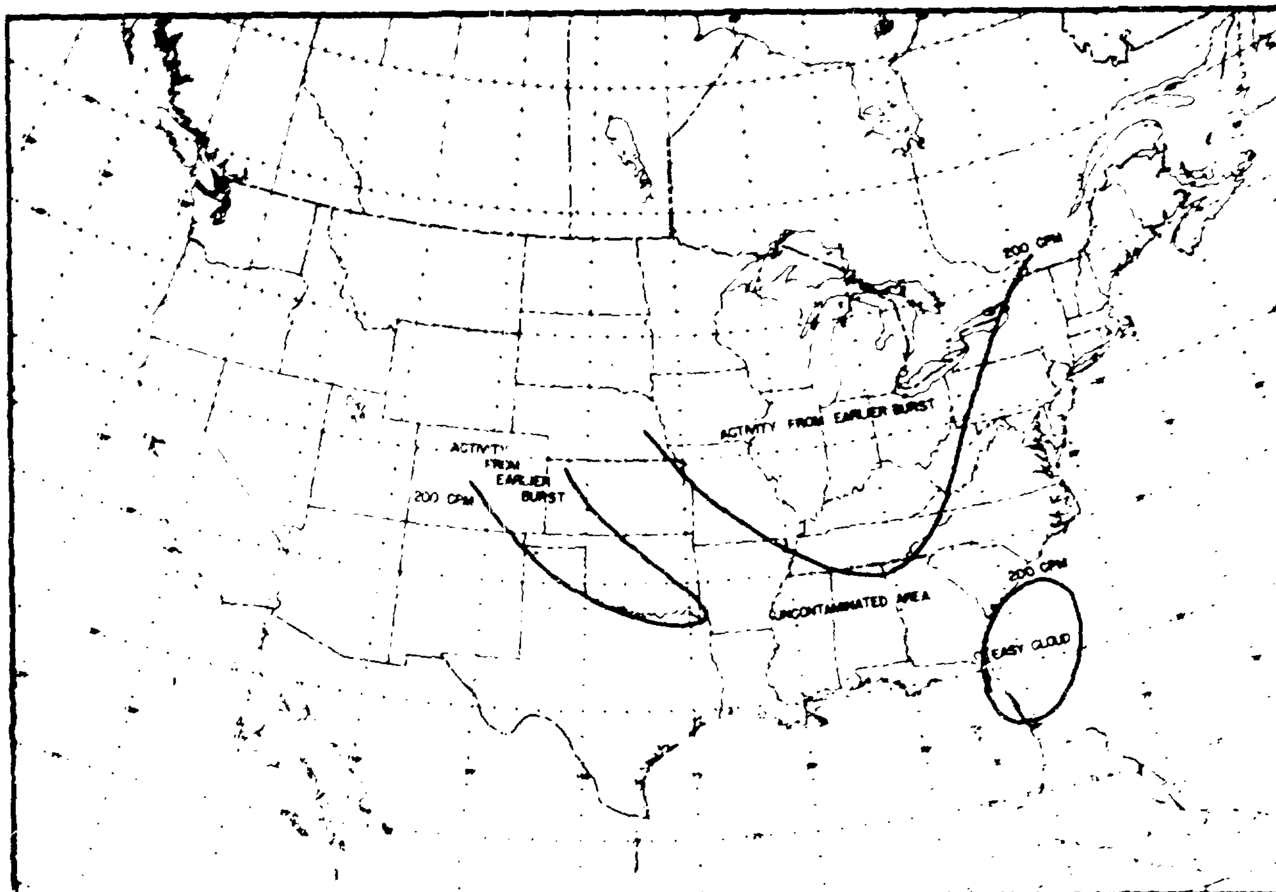


Fig. 3.45 Areas of Radioactive Debris at 400 mb (24,000 Feet) at 1800 GCT 7 November 1951

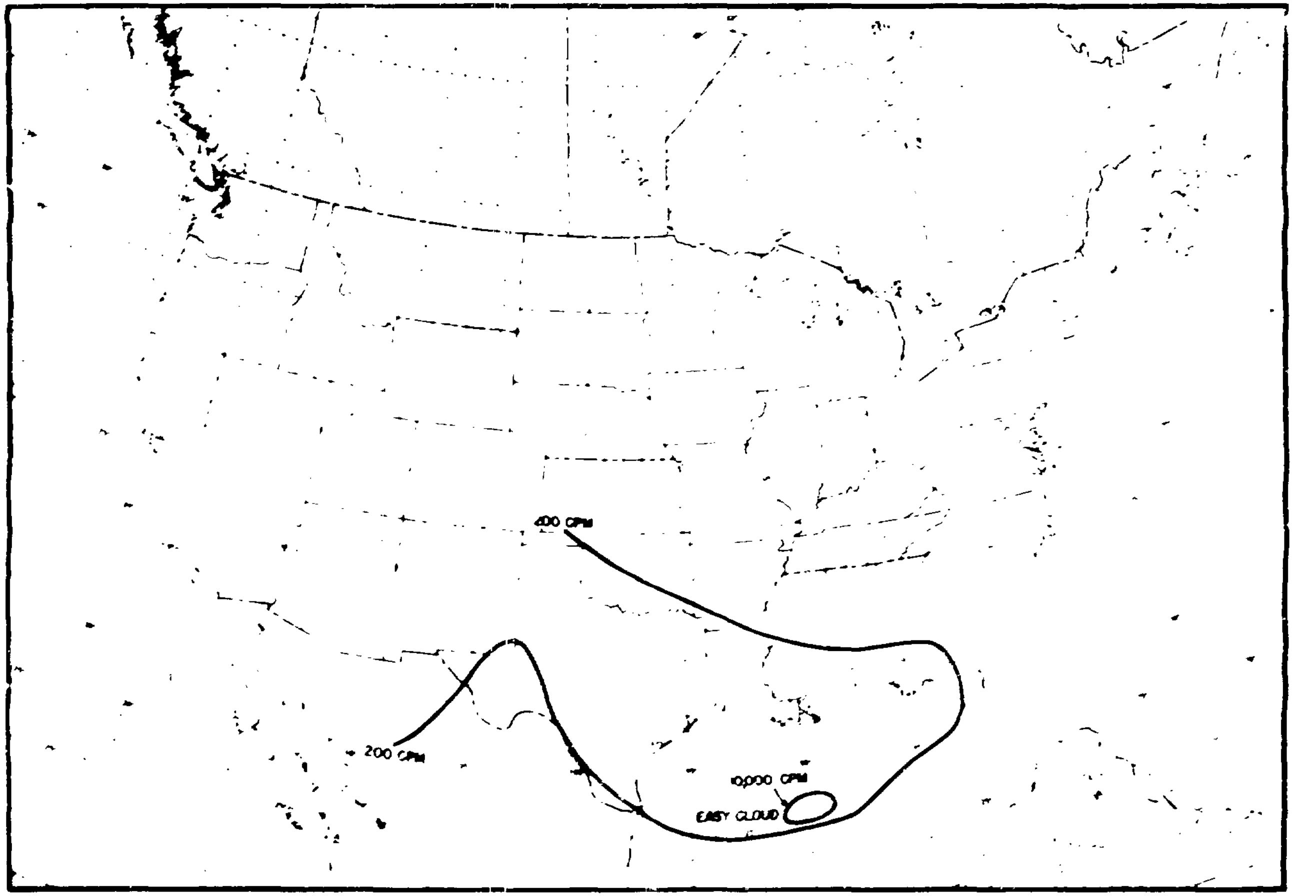


Fig. 3.46 Areas of Radioactive Debris at 700 mb (10,000 Feet) at 1800 GCT 7 November 1951

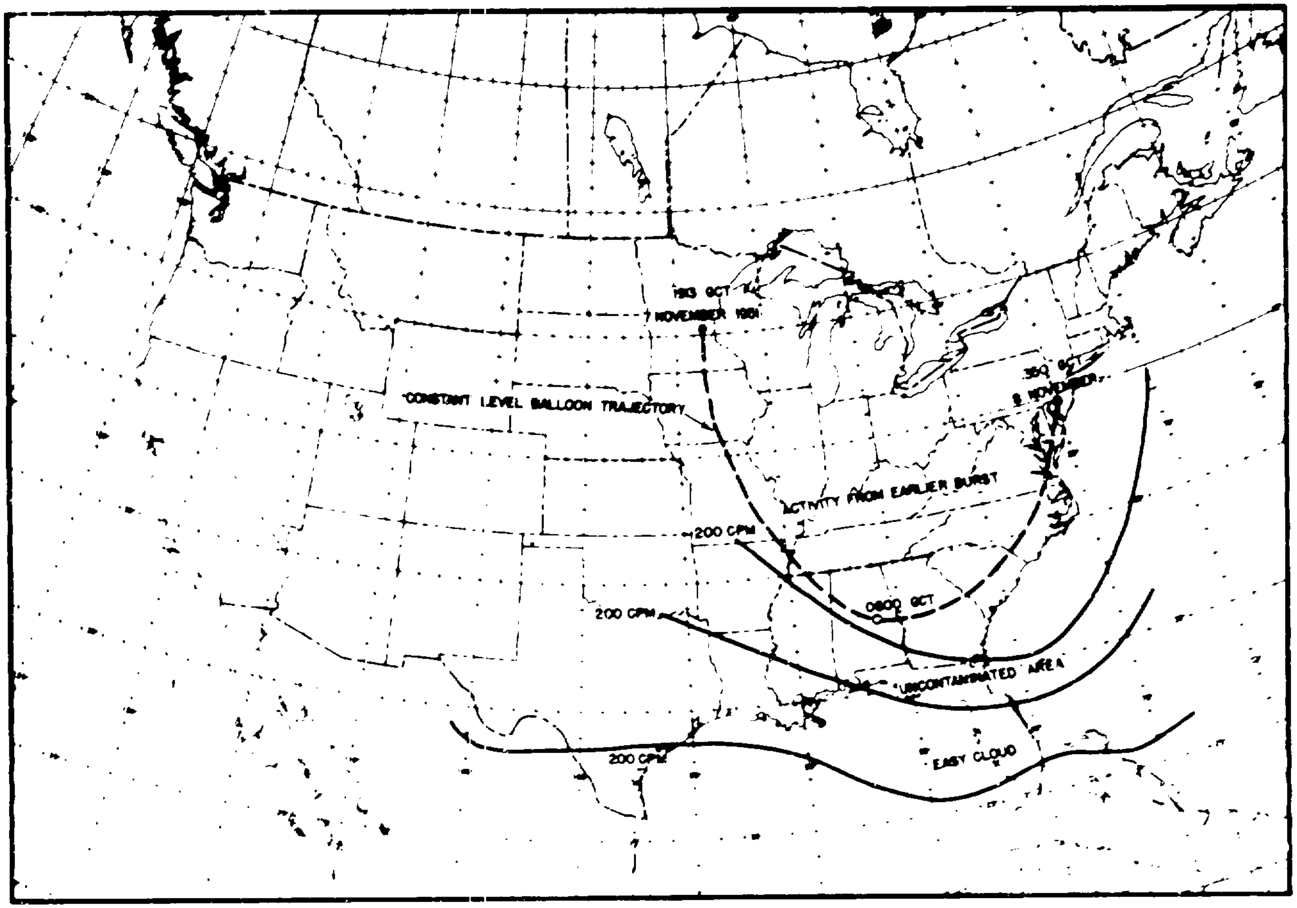


Fig. 3.47 Areas of Radioactive Debris at 400 mb (24,000 Feet) at 1800 GCT 8 November 1951

3.5.4 Distribution of Radioactive Debris at the Ground

An inspection of Figure 3.35 will show that the upper level trajectories carried the Easy debris along the southern limit of the surface monitoring network. Since no southerly winds existed in the lower 10,000 to 20,000 feet, the only stations that could have collected material from the Easy burst are Del Rio and Corpus Christi, Texas, and Tampa, Florida. No precipitation occurred at the time the high-level cloud passed overhead, so if any material was collected at the surface, it was brought down by turbulent diffusion and gravitational settling.

The tray sample at Del Rio taken from 1845 GCT 5 November to 1845 GCT 6 November 1951 showed a significant increase of activity (Figure A.19). Since all upper level portions of the Easy cloud had passed overhead before the end of that sampling period, it would seem logical to associate this activity with the Easy cloud. Examination of the meteorological evidence indicates that this is not correct. Much of the air of the lower atmosphere north of this station was contaminated by earlier tests. On 2300 GCT 5 November a cold front passed Del Rio and the air from the north pushed southward over the Mexican border. The increase of activity that occurred as the air pushed down from the contaminated area suggests very strongly that the increased activity was due to residual debris from other tests rather than fallout from a cloud passing far overhead. The data from Corpus Christi are ambiguous because the activity on the tray increased from the 6th to the 7th but at the same time the activity on the gummed paper decreased.

It can only be stated that in general the data from Del Rio and Corpus Christi suggest that the samples collected on the 6th and 7th were not debris from the Easy cloud.

The tray samples collected at Tampa, Florida during the period from 7-15 November 1951 (Figures A.20 - A.28) did not show any significant increase of activity even though this station was in the most favorable position to collect fallout. It appears that no surface samples of debris were obtained from the Easy burst. No doubt material from this burst mixed with the material from other bursts and was subsequently collected at the surface but it cannot be separated and identified.

3.6 JANGLE SURFACE

The Surface detonation occurred at 1700 GCT 19 November 1951.

3.6.1 Initial Cloud Dimensions

The cloud moved northeastward, away from the theodolite, so that reliable reports of cloud height were easily obtained. A maximum height of 15,000 feet msl was reached in 4 minutes and 45 seconds. The base of the primary mushroom was 11,000 feet. A second mushroom, composed of surface dust in an air current which was heated by the hot crater, formed and its top reached a level just beneath the base of the first mushroom. In a minute or two diffusion had closed the gap between them, but the rosy-colored upper mushroom remained distinctly separated from the lower, grayish-white mushroom. Directional wind shear carried the rosy top to the north-northeast and the lower part directly northward. The clouds were observed to rise and fall as they drifted over the first ridge of hills. During the period of observation the upper mushroom grew from 4900 feet in diameter 6 minutes after the burst, to 9100 feet after 11 minutes; to 12,400 feet after 16 minutes; and to 14,400 feet after 21 minutes.

3.6.2 Initial Cloud Track

The topmost portion of the cloud was tracked directly over Great Salt Lake, Figure 3.48, while the lower portions followed valleys toward the north. Further progress of this low level cloud is given in Section 3.6.4.

3.6.3 Long-Range Cloud Path

Long-range trajectories of the primary cloud from the Surface burst are shown in Figure 3.49 for the gradient wind level (2,000-3,000 feet above the surface), the 700-mb level (10,000 feet msl), and the 14,000-foot msl level. (Details of the distribution of radioactivity associated with the gradient level trajectory will be discussed in Section 3.6.4) (Figures 3.50-3.58) The two higher trajectories are based on data from the LARK WILLIAM flights 17-21 (Figures 3.50-3.58) and on the meteorological trajectory from the burst site. At the time of the burst, a ridge of high pressure extended from New Mexico northward into Canada, and produced southwesterly winds above 10,000 feet over Nevada. As the debris from the upper mushroom moved northeastward, the ridge moved eastward rather rapidly so that the primary cloud continued on a northeastward course.

It is probable, however, that some of the diffuse material actually travelled with a speed some 5-10 percent greater than that of the primary cloud at 14,000 ft, passed the ridge line, and moved southward before crossing the 84th meridian. Such a movement accounts for the activity encountered on the LARK WILLIAM 17 flight

(Figure 3.56) at 39°N, 84°W on 21 November at 0415-0445 GCT. A decay curve made by the AEC NYOO[7] identified this material as debris from the Surface burst.

Figures 3.59 and 3.60 show estimates of the contaminated areas at 14,000 feet and 700 mb, respectively, at 1800 GCT 21 November 1951. In both figures, the delineation of the core of the cloud and of the activity in the vicinity of 84°W is fairly well fixed by LARK WILLIAM flights 17-21 (Figures 3.50-3.58). However, the delineation of activity in the leading and trailing portions of the cloud is subject to considerable doubt since no measurements of activity were made in these regions. The tongue of contamination reaching southward over the Eastern States was Surface debris which moved ahead of the primary cloud and curved southward. The material indicated south of the Great Lakes and in the Mississippi Valley was undoubtedly contamination from earlier bursts. Delineation of the southern boundary of the debris in the southwest and west is very uncertain; the northwest boundary is drawn to coincide with a marked wind shear in advance of an outflow of presumably uncontaminated air from the northwest.

3.6.4 Distribution of Radioactive Debris at the Ground

The movement of the low-level debris from the Surface burst was dominated, during the six to twelve hours following the burst, by the relatively strong south winds associated with a high pressure cell centered over northwestern Colorado. The lower mushroom moved almost directly northward through the north-south valleys which are a topographic feature of the region.

Although meteorological observations are non-existent in the immediate area from the Test Site northward to Elko, Nevada, it is possible to reconstruct the probable path of the low-level debris by considering the topography, the few near-by meteorological observations available, and the mobile fallout monitoring by the team from the AEC New York Operations Office.[8]

For the Surface burst, mobile ground stations were established at Wendover, Delta, and Salt Lake City, Utah, at Burley and Idaho Falls, Idaho, and at Elko, Nevada. The filters on the dust samplers were generally changed at frequent enough intervals to show the time of first arrival and of maximum activity, within narrow limits.

---

7 ibid., p. 59

8 ibid. pp. 42-47

Figure 3.61 shows the locations of the mobile stations, as well as some of the Weather Bureau stations used in the routine fallout monitoring program, and gives the reconstructed path of the debris at the gradient level. Shown at each of the mobile stations with significant activity is the concentration (d/m/meter^3, extrapolated to the time of collection) found on the most active dust filter, and the time at which the observation was made.

At Elko, the first sample taken contained the greatest activity found on any of the filters, indicating that debris arrived at this station before the sampling began. However, the great activity found on the first filter and a consideration of the gradient wind pattern, makes it likely that this filter was exposed very near the time of maximum activity. A mean wind of about 35 knots would have been necessary to transport debris to Elko by the time of the first sample. Although somewhat lighter winds existed near the Test Site, there is evidence that higher wind speeds existed to the north. The channeling effect of the north-south ridges also serves to increase the wind speed in the valleys between the Test Site and Elko.

From Elko, the gradient winds indicated a trajectory passing northward over Boise, Idaho, and then northwestward to the Columbia River Valley, where the winds became light and variable.

Fallout monitoring detected high activity at Boise from 21 to 27 November and moderately high activity at Pendleton, Oregon, on the 21st and 22nd (Figures A.34 and A.35). The persistence of debris in the vicinity of Boise can be attributed to the light, variable surface winds which existed throughout the period.

The absence of activity in the mobile observations at Delta and Salt Lake City is a result of discontinuing the observation before the arrival of the debris. For example, at Salt Lake City, operations continued only until 1600 GCT, 20 November, and showed no significant activity. However, the routine fallout monitoring at the Salt Lake City Weather Bureau station shows increased activity during the two succeeding 24-hour periods.

In addition to the area of persistent activity near the ground in the vicinity of Boise, another area of pronounced activity occurred in the eastern Dakotas, Nebraska, and western Minnesota on 21 November (Figure A.34). Although best defined on the 21st, this area of high activity can be followed as it moved eastward to the coast on the 22nd and 23rd (Figures A.35 and A.36). An interesting feature of this activity is that the surface weather map indicated an outbreak of fresh polar continental air from northern Canada which would be expected to be uncontaminated. At 1830 GCT on the

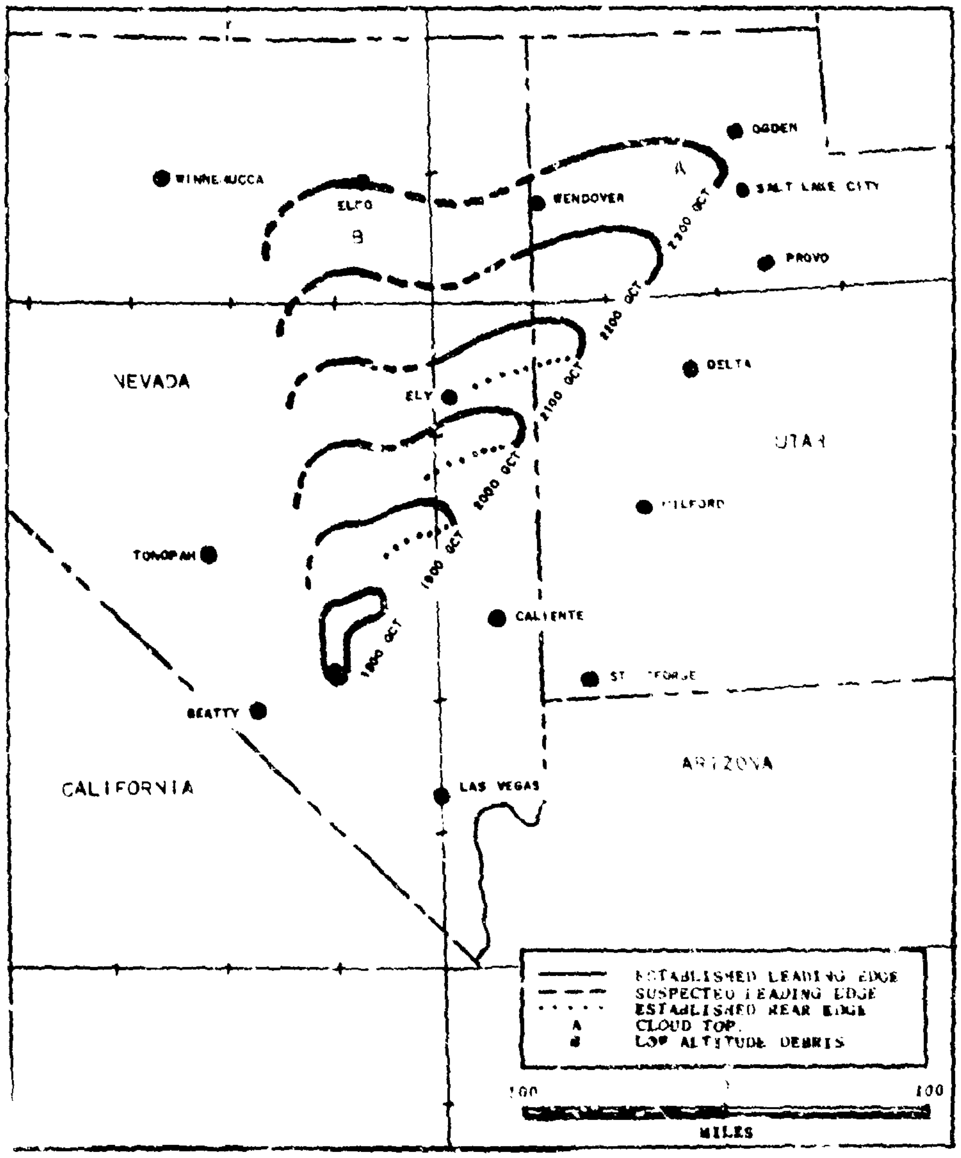


Fig. 3.48 Initial Movement of the JANGLE Surface Cloud. Detonation at 1700 GCT 19 November 1951; maximum height, 15,000 feet.

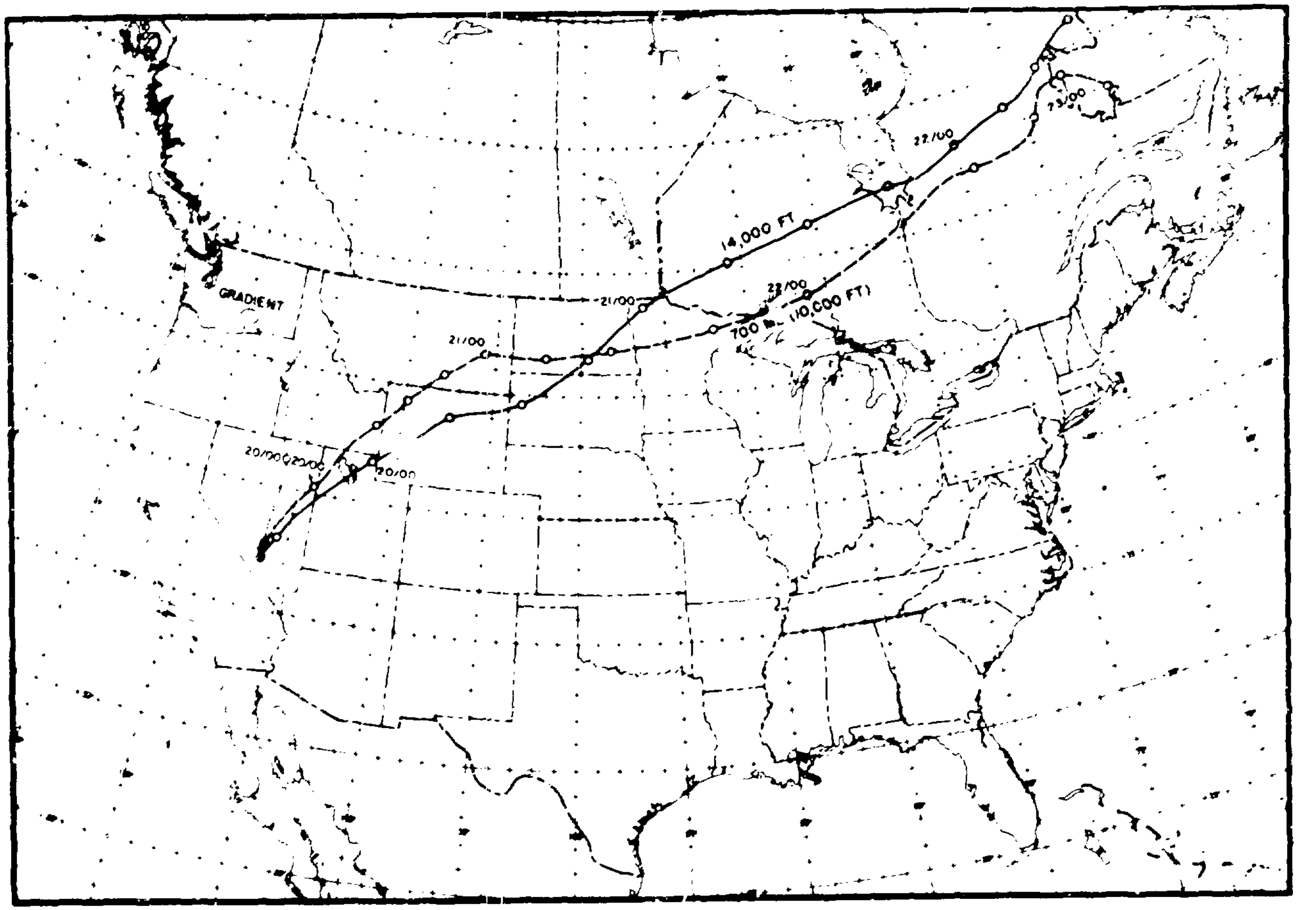


Fig. 3.49 Trajectories of the Primary Cloud from JANGLE Surface

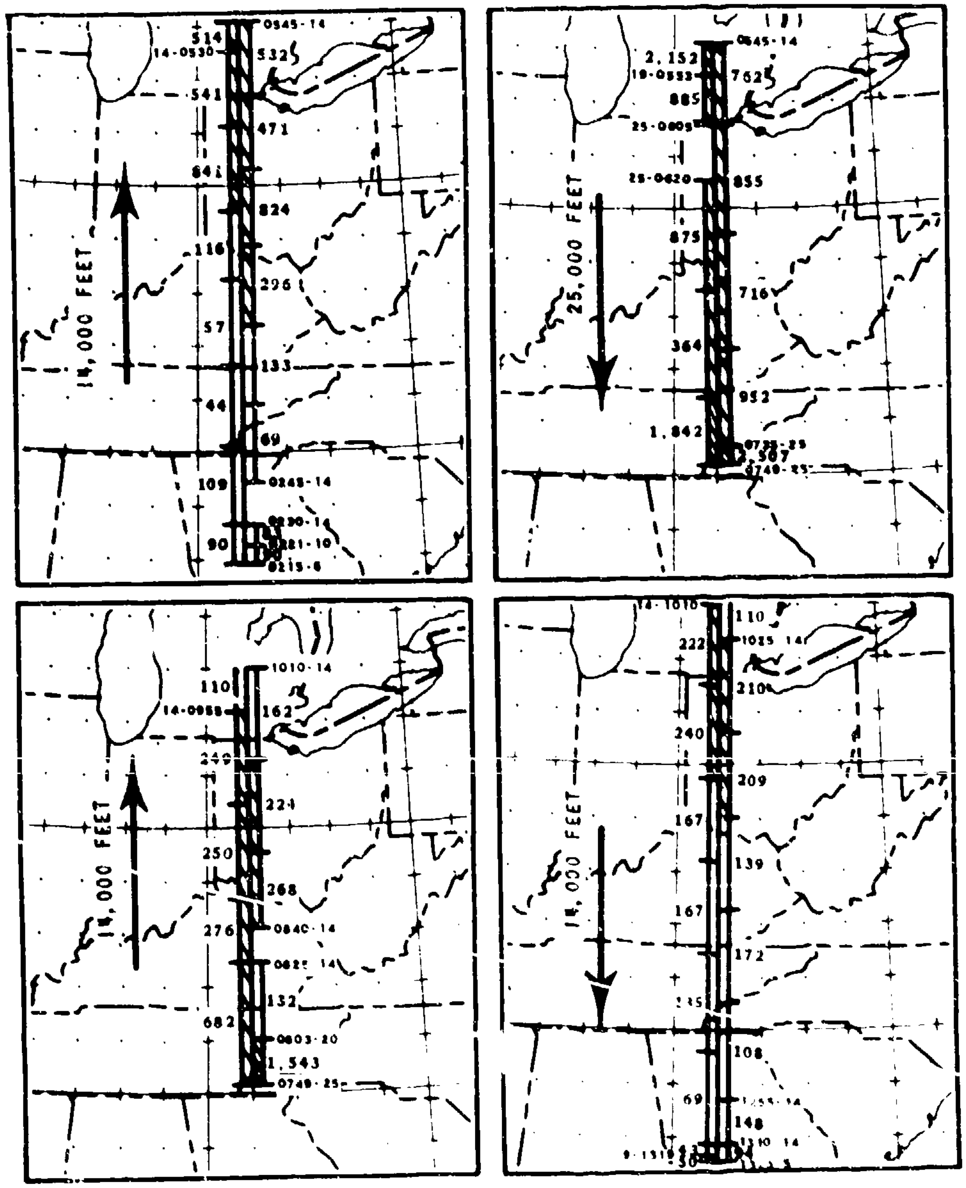


Fig. 3.50 LARK WILLIAM 17, 21 November 1951

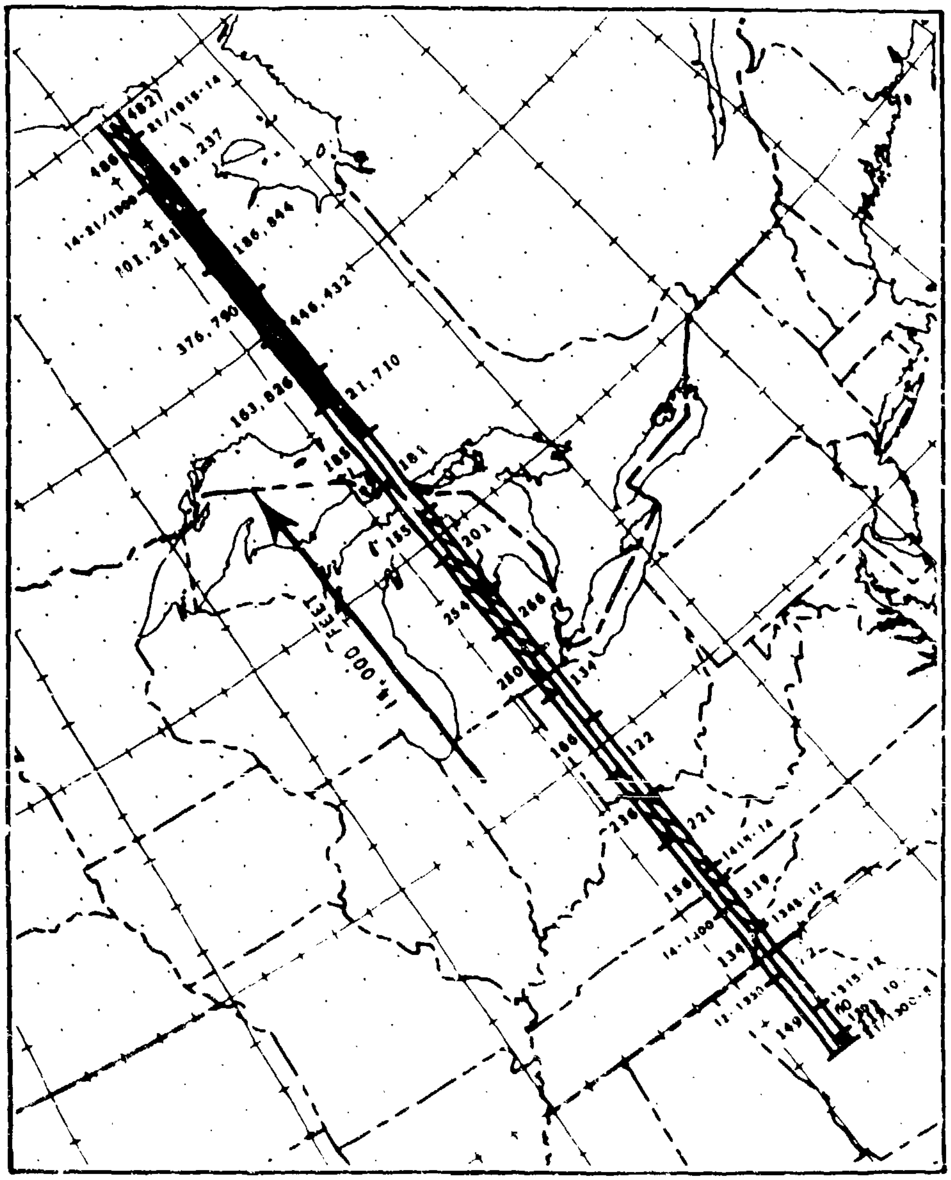


Fig. 3.51 LARK WILLIAM 18, 21-22 November 1951 - Northbound

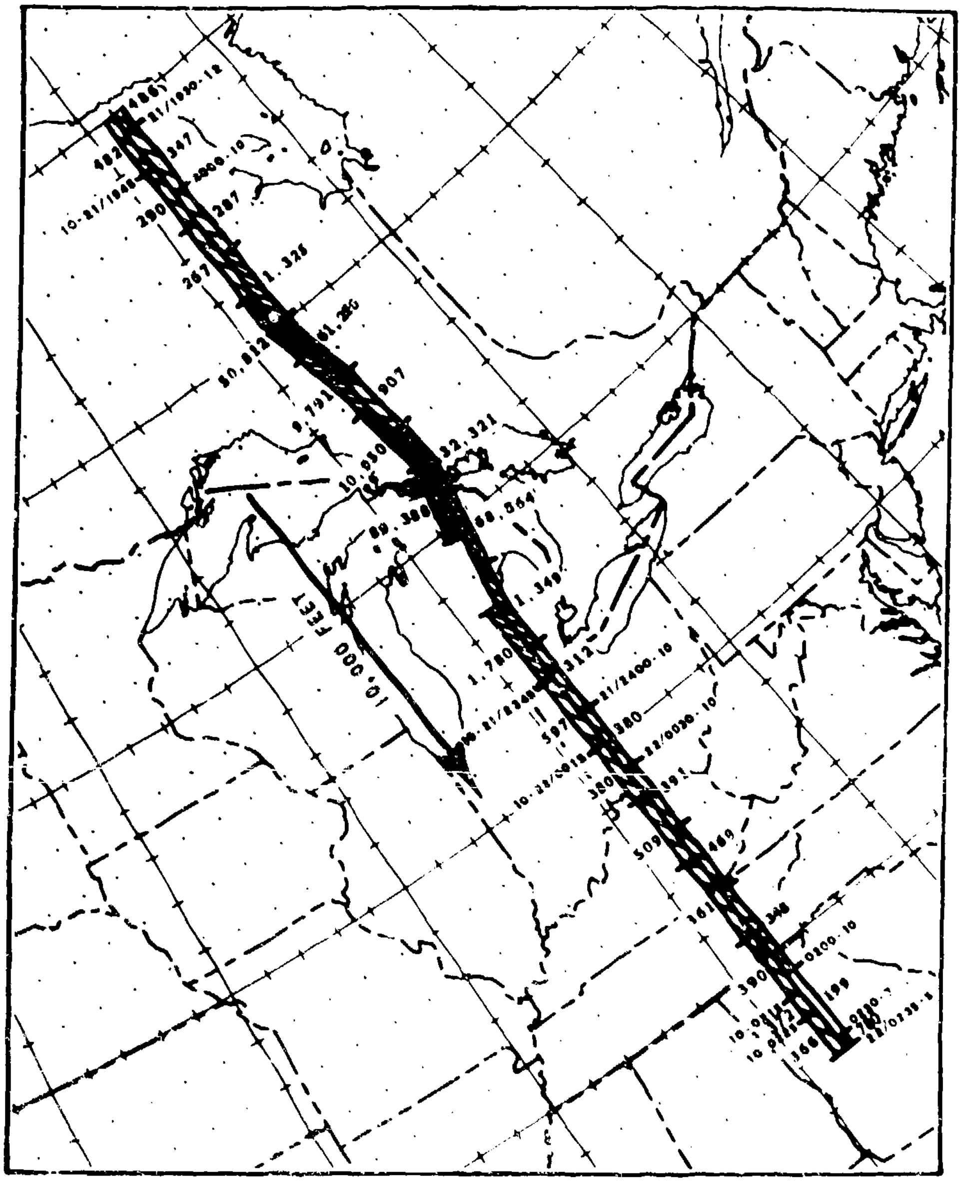


Fig. 3.52 LARK WILLIAM 18, 21-22 November 1951 - Southbound

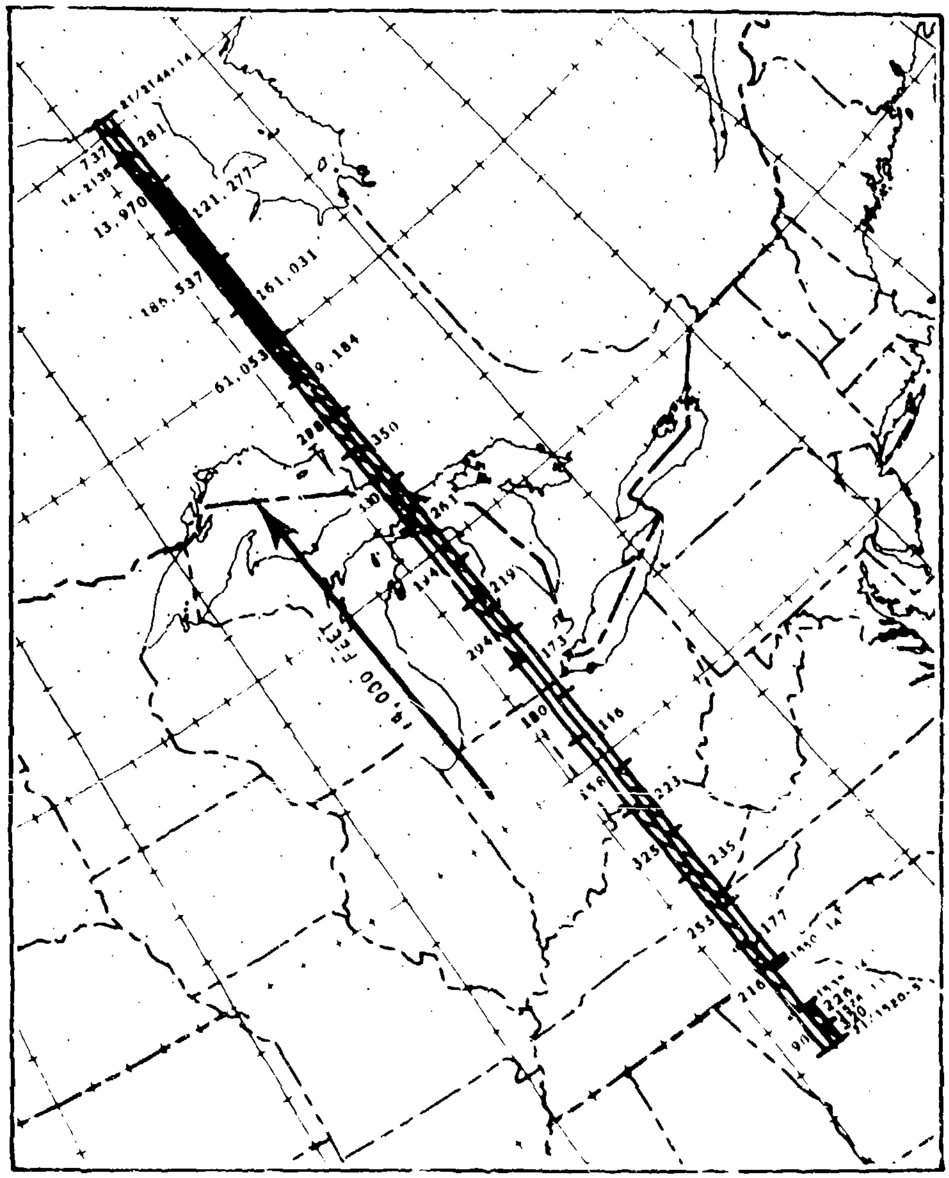


Fig. 3.53 LARK WILLIAM 19, 21-22 November 1951 Northbound

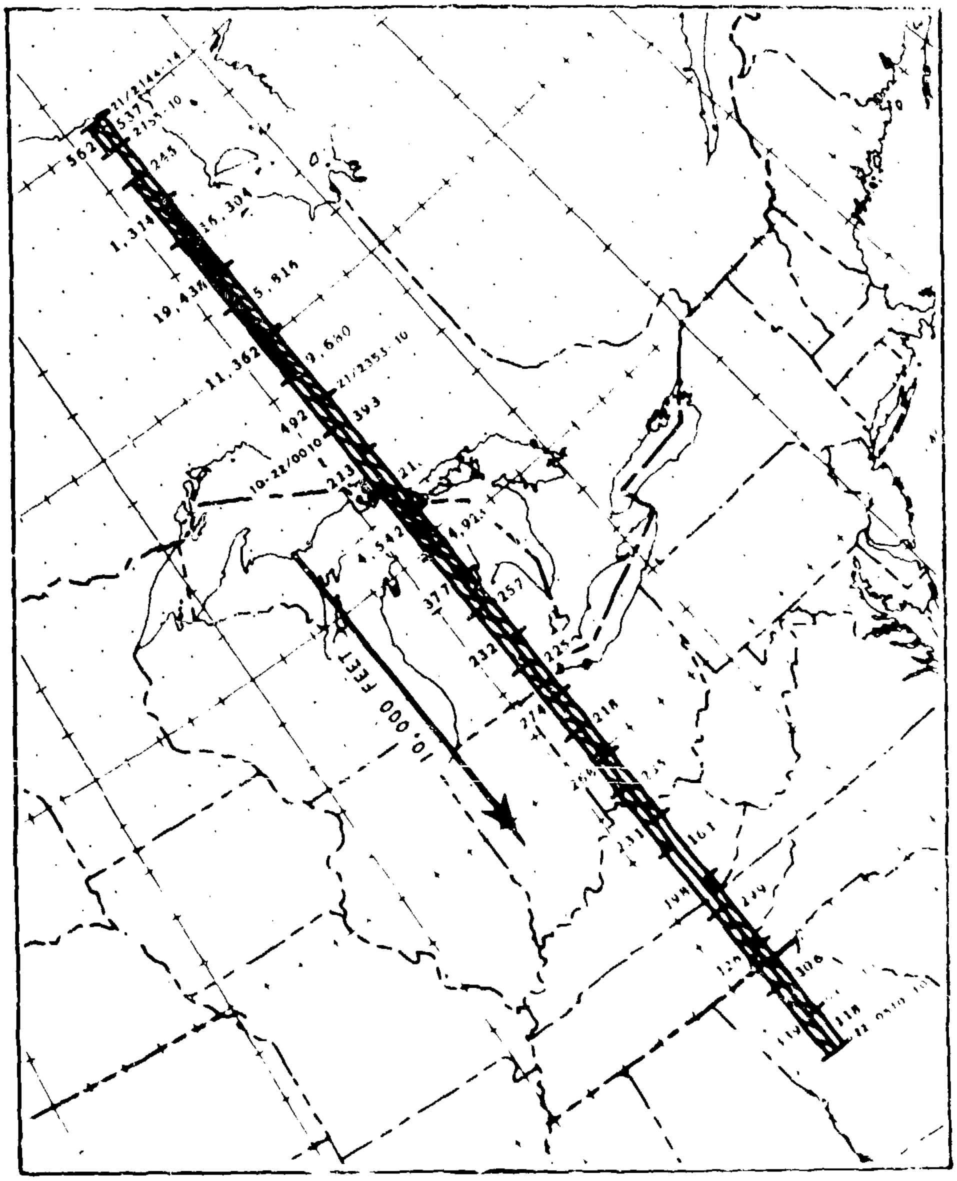


Fig. 3.54 LARK WILLIAM 19, 21-22 November 1951 - Southbound

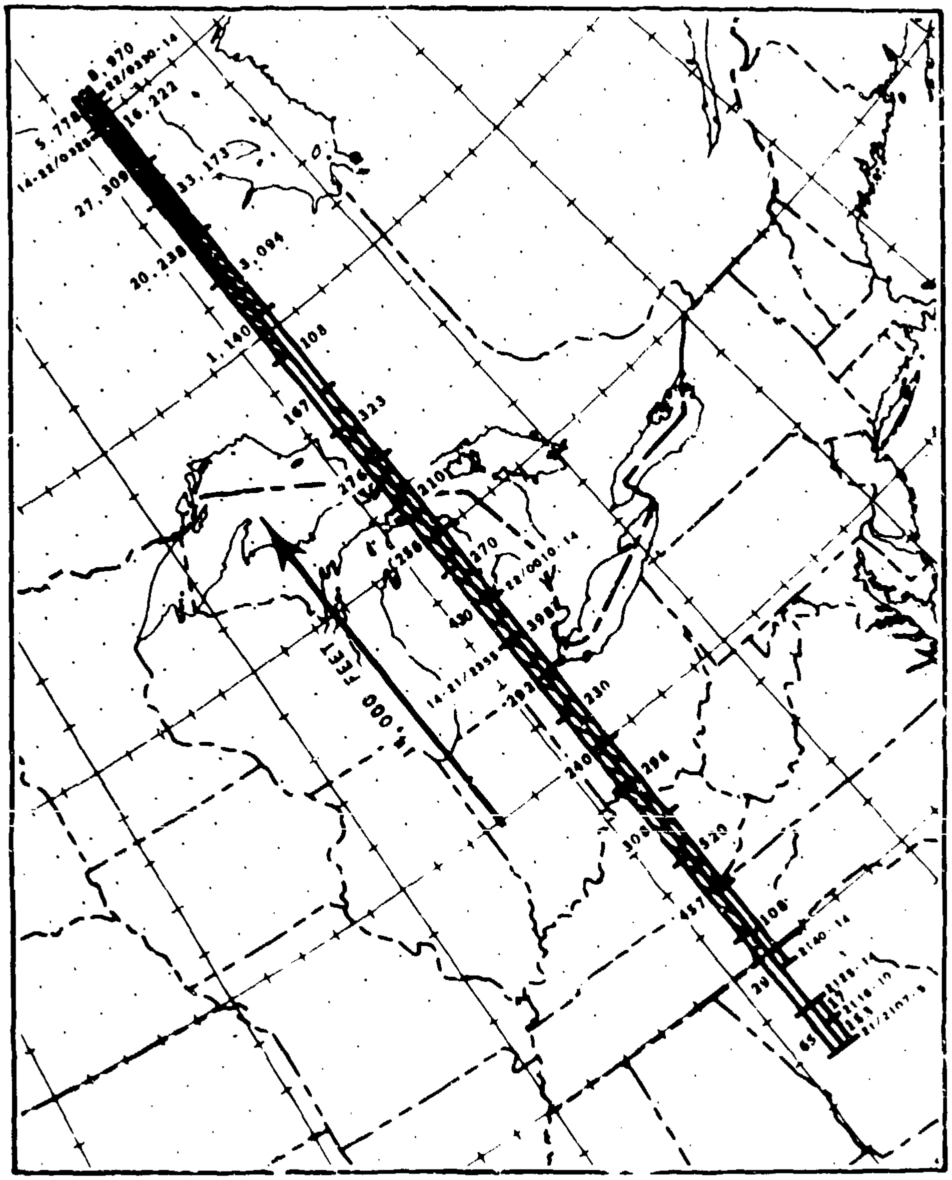


Fig. 3.55 LARK WILLIAM 20, 21-22 November 1951 - Northbound

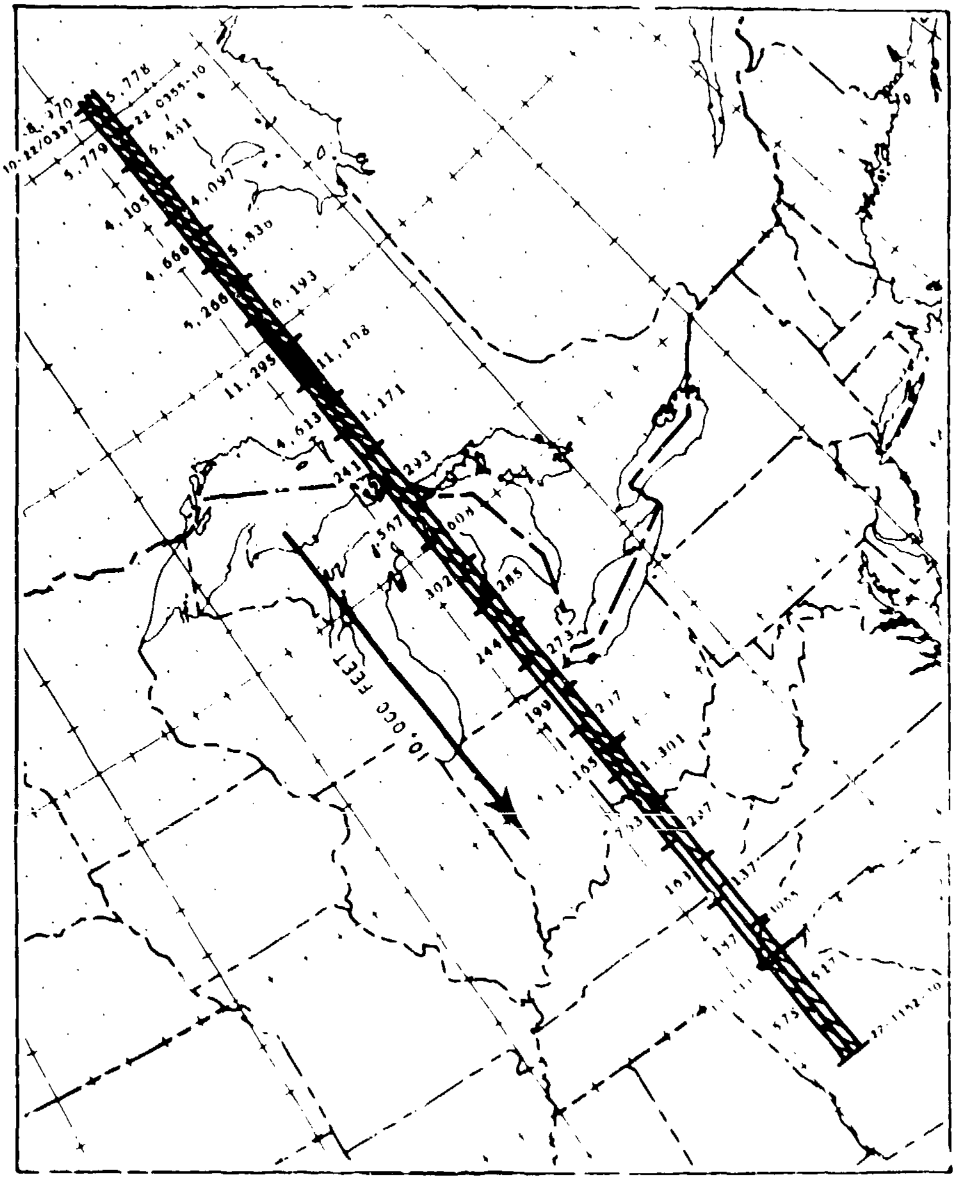


Fig. 3.56 LARK WILLIAM 20, 21-22 November 1951 - Southbound

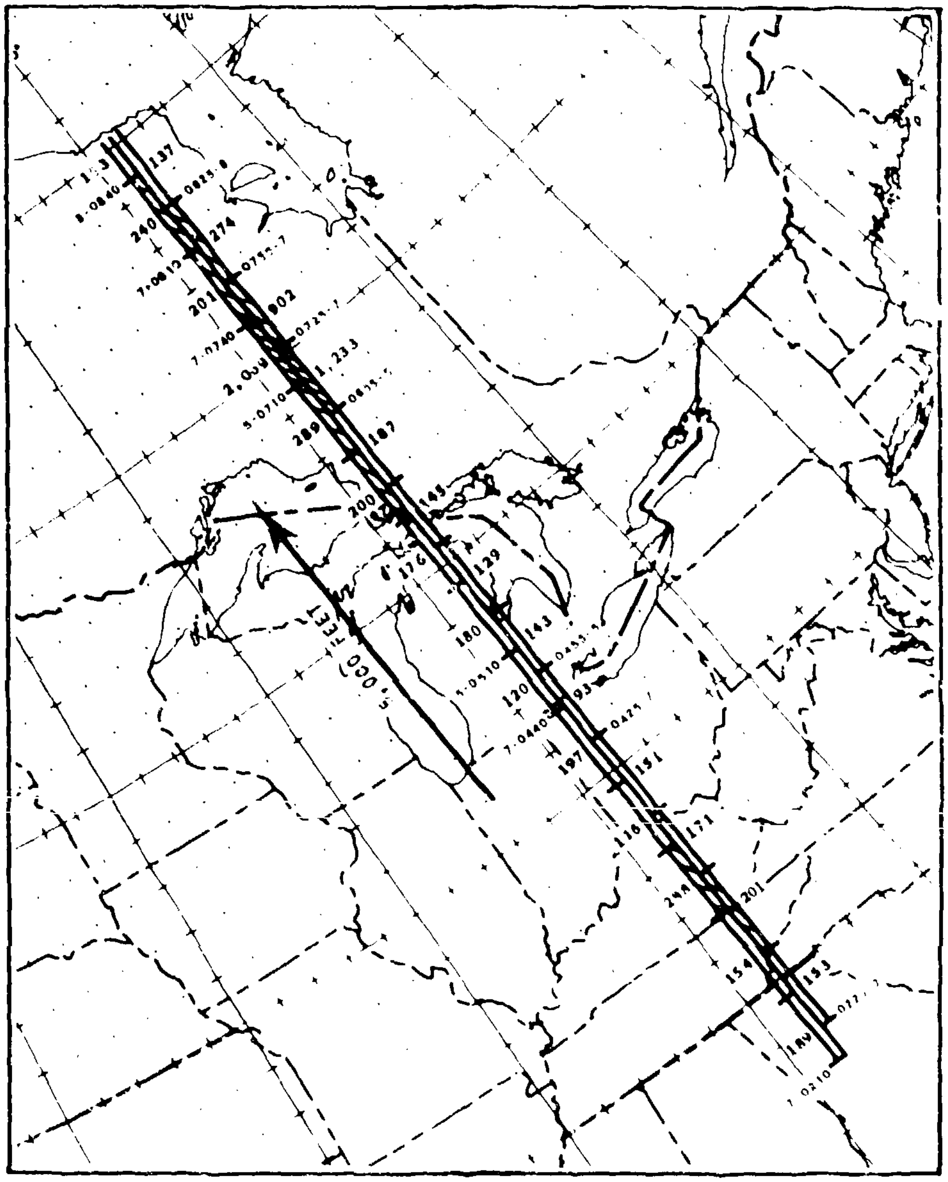


Fig. 3.57 LARK WILLIAM 21, 22 November 1951 - Northbound

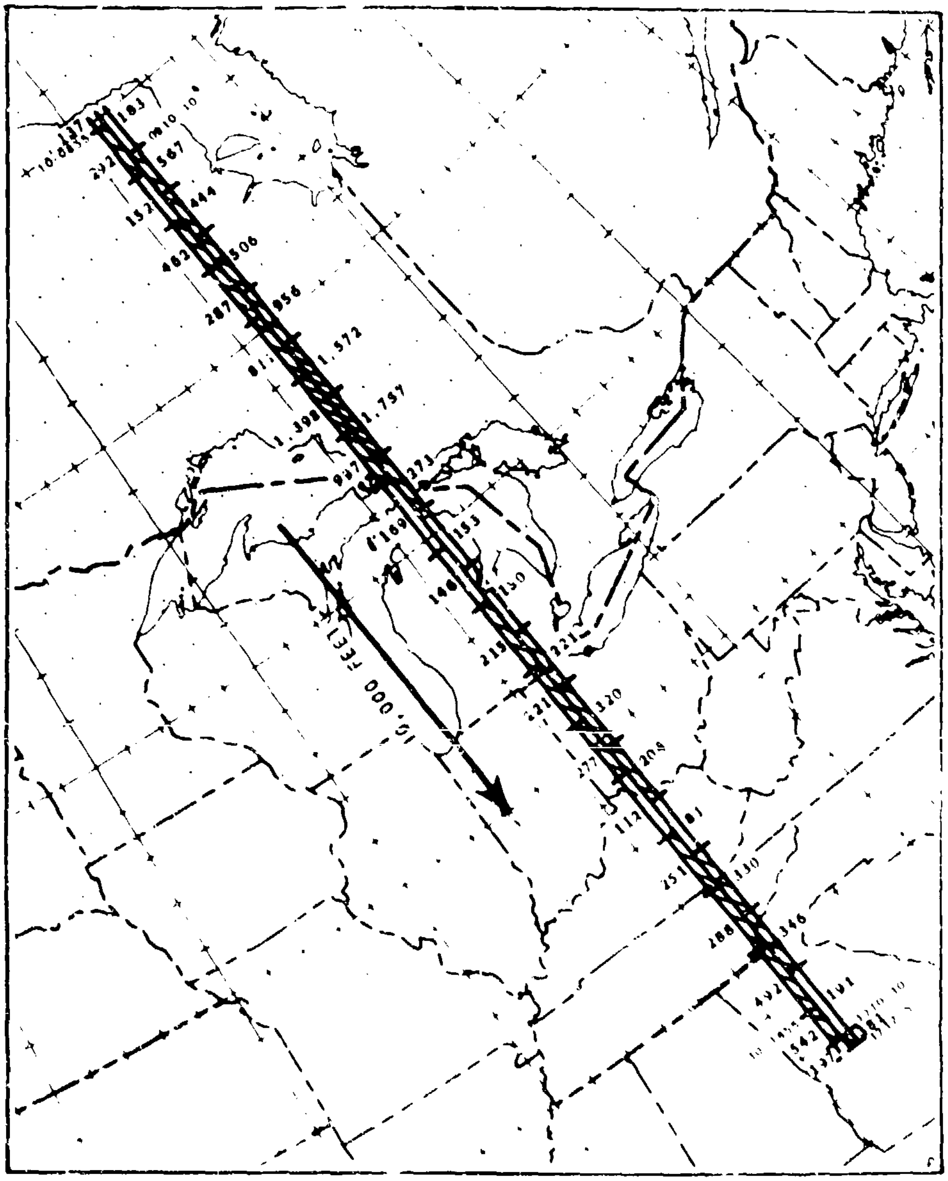


Fig. 3.58 LARK WILLIAM 21, 22 November 1951 - Southbound

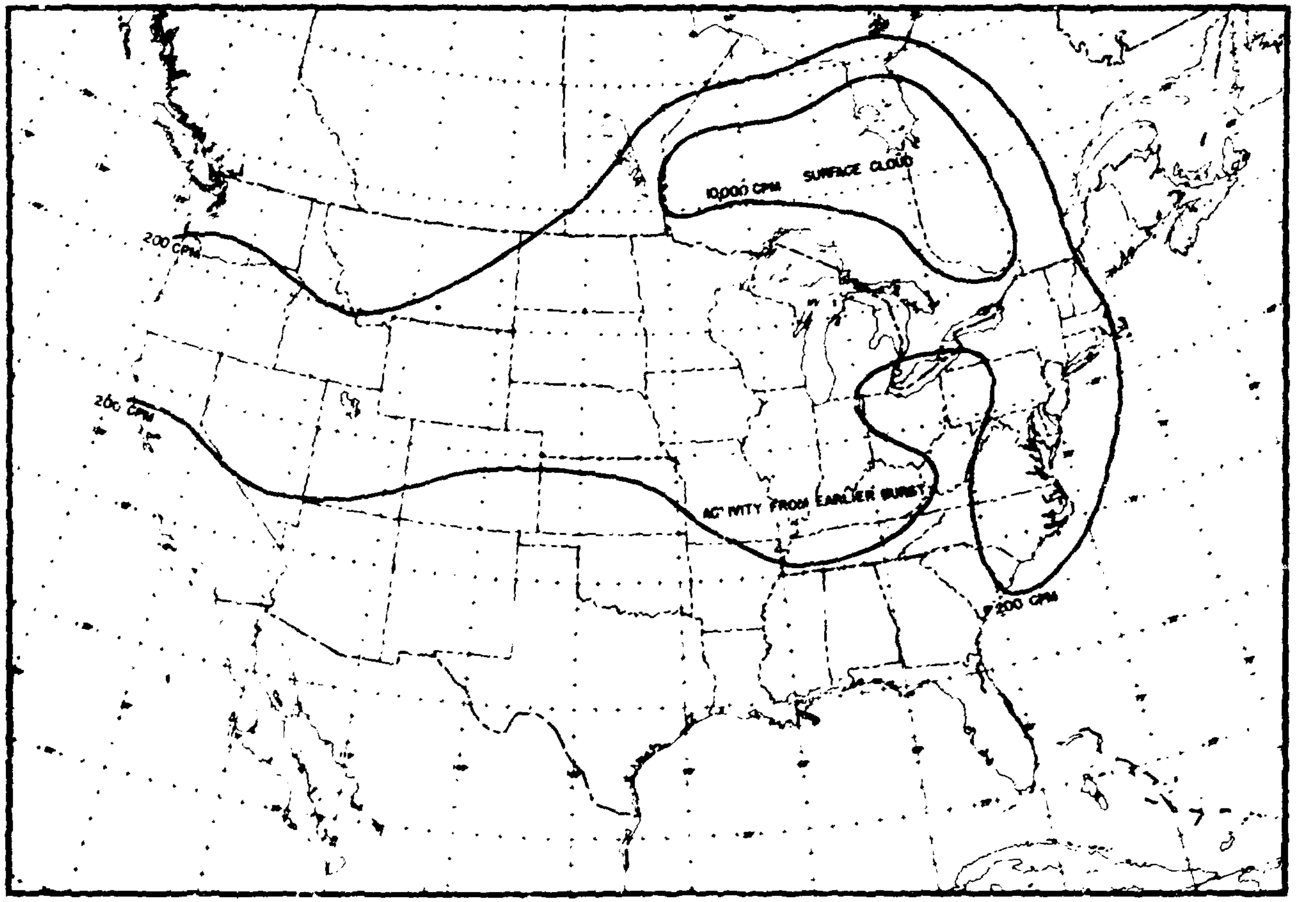


Fig. 3.59 Areas of Radioactive Debris at 14,000 Feet at 1800 GCT 21 November 1951

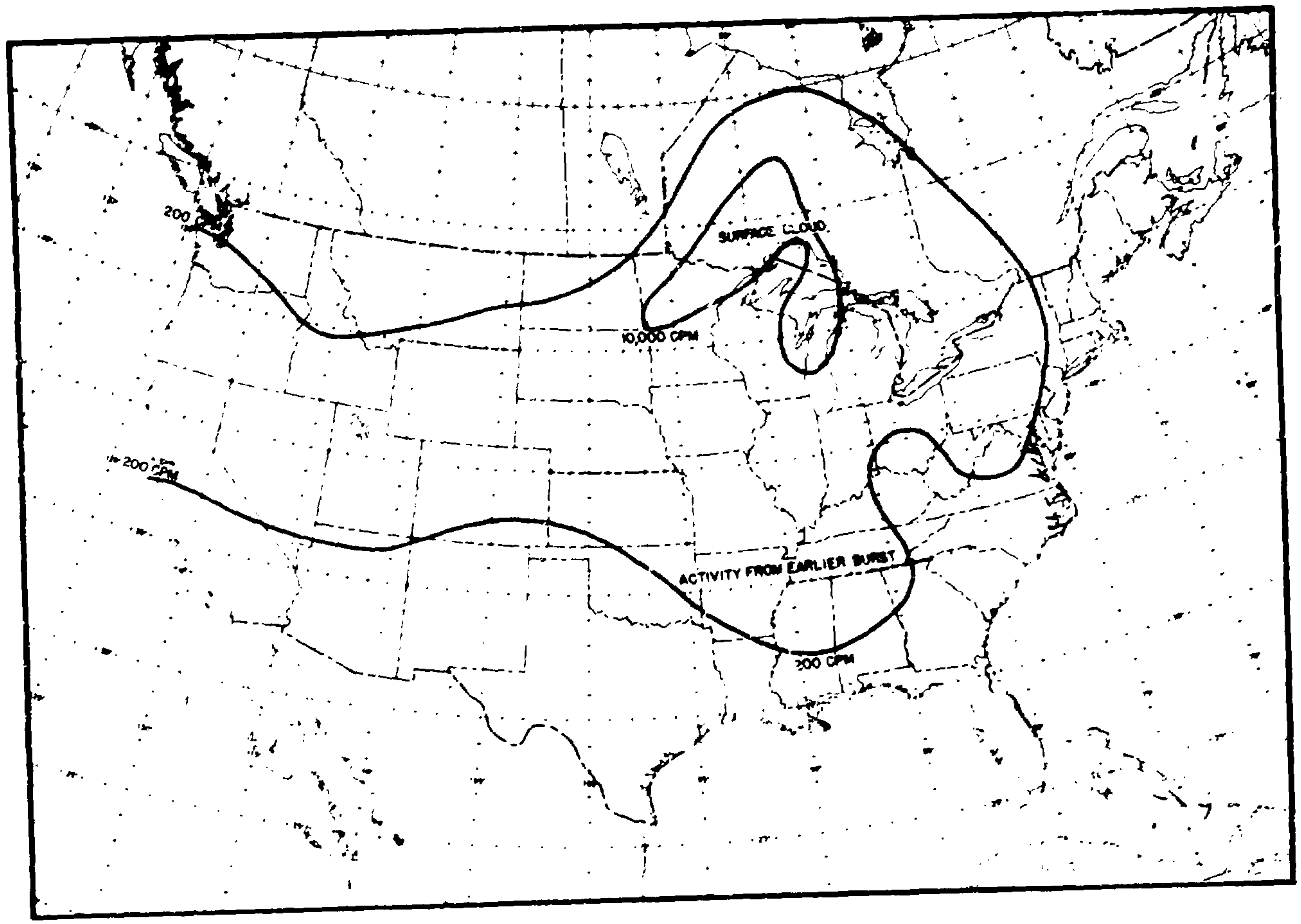


Fig. 3.60 Areas of Radioactive Debris at 700 mb (10,000 Feet) at 1800 GCT 21 November 1951

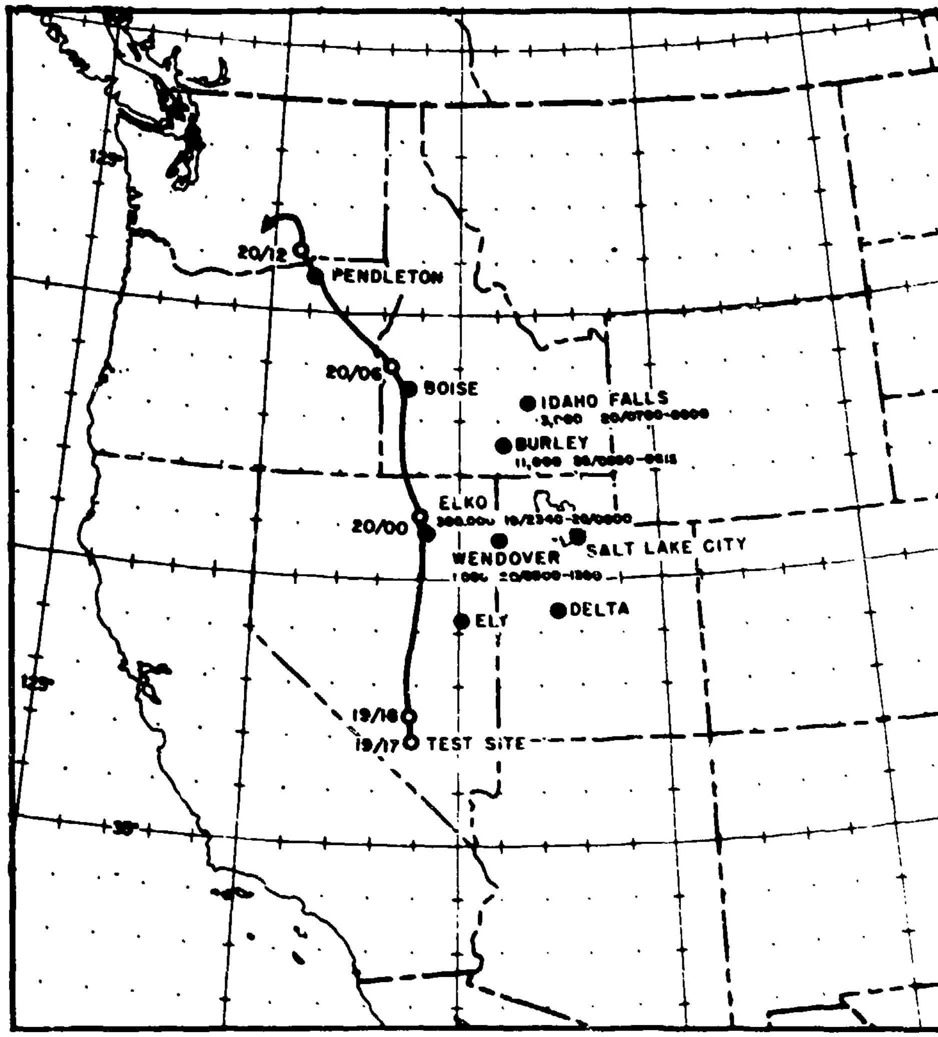


Fig. 3.61 Movement of Low-Level Debris from the Surface burst

21st, the leading edge of the polar air extended from the western tip of Lake Superior southwestward to Omaha, Nebraska, and then westward through central Nebraska, slightly in advance of the region of maximum activity indicated in Figure A.34. Since no precipitation of any consequence occurred during the sampling period at stations in this area, much material must have been carried downward in the turbulent zone associated with the cold front.

3.7 JANGLE UNDERGROUND

The Underground explosion occurred at 2000 GCT 29 November 1951.

3.7.1 Initial Cloud Dimensions

The top of the cloud column had apparently stabilized at 10,300 feet msl at 4-1/2 minutes, but two minutes later a small projection formed on top of the cloud, adding 200 feet to the height. Subsequent rising and falling occurred as the cloud moved over the ridges to the northeast.

3.7.2 Initial Cloud Track

The limited height of this cloud was not sufficient to expose it to very strong winds, so that its movement was much slower than that of previous clouds. One tracking airplane was able to make numerous checks of the edges of the upper cloud, yielding a very accurate cloud path for the short period of operation as shown in Figure 3.62. The lower cloud hung back and the trailing edge remained at or near the detonation point for several hours before moving slowly northward. When the nocturnal drainage current reestablished itself, some of this debris moved back southward over the Control Point and camp areas.

3.7.3 Long-Range Cloud Path

A trajectory of the Underground cloud at the 700-mb level is shown in Figure 3.63. Also shown is the approximate path taken by the debris in the lower levels. This lower-level trajectory will be considered in Section 3.7.4.

The only long-range detection flight to intercept this cloud was LARK WILLIAM 22, shown in Figures 3.64 and 3.65. This flight was dispatched to determine whether or not the cloud passed over the Rocky Mountains, and it encountered moderately strong activity, around 40,000 cpm, near Rapid City, South Dakota, which can, without question, be attributed to the Underground cloud.

The forecast that led to this flight was thus a correct one, but the forecasting for additional detection of this cloud was less fortunate. Four other flights, shown in Figures 3.66-3.72, were made along the 84th meridian but were not successful in detecting the cloud. Apparently the debris passed well north of the latitudes covered by the flights.

3.7.4 Distribution of Radioactive Debris at the Ground

The New York Operations Office, A.E.C., established special mobile monitoring stations for the Underground burst at Ogden, Provo, Delta, and Wendover, Utah; Elko, Nevada; and Rock Springs, Wyoming. These were in addition to the regular network of fallout monitoring stations that were in operation throughout the series of tests. The data available from these special monitoring stations has been published.[9] These records show a maximum of surface concentration of debris at Elko, Nevada - considerably to the west of both the trajectory at the 700-mb level (Figure 3.63) and the path of the cloud shown by the close-in detection (Figure 3.62). Meteorological data are insufficient to provide a completely satisfactory explanation of the arrival of this debris at the surface at this western location. By inference it must be concluded that the channeling effect of the north-south ridges and valleys was such that the debris was carried northward through the valleys at levels below 10,000 feet. The available winds aloft data for stations near the path that must have been taken by the active material are given for the applicable times in Figure 3.73. From the time-versus-activity graph of the airborne debris at Elko, it is apparent that radioactive material from the Underground burst was at that station within 12 hours after the detonation. This requires a movement at the rate of approximately 20 knots, a speed somewhat greater than the wind speeds measured at the stations nearest to the most likely path of the debris. It is probable that, accompanying the channeling effect of the mountains, there was an acceleration of the wind through the valleys just as in the period when the Surface debris moved northward.

At Provo, Utah, the data collected by the air filtering unit shows that the peak activity recorded during the observation period occurred only four hours and forty minutes after the time of the burst. If this activity resulted from debris from the Underground cloud, it is necessary that it moved at a rate of approximately 60 knots. This speed is far in excess of any wind speeds observed between the surface and 10,000 feet during this period. In view of these reported speeds, it

---

[9] *ibid.* pp. 47-53

seems unrealistic to ascribe this peak in the measured activity to the Underground burst. It is more likely that a local shift in the wind direction accompanied by an increase in speed, perhaps a downslope wind associated with the nocturnal cooling by radiation, caused debris from the Surface cloud to be lifted from the surface and transported to the monitoring station. Meteorological data are not available from Provo so the validity of this supposition cannot be established.

The second maximum in the recorded activity at Provo represents material which has fallen from the primary cloud which passed over Provo at approximately 1000 GCT 30 November.

The data collected at Ogden, Utah, do not show a clear-cut maximum of activity. Because of the relatively short period during which measurements were made, it is not possible to establish the level of background activity for this region. It is possible that the measured variations simply represent fluctuations in the background activity, although the broad peak between approximately 1000 and 1800 GCT 30 November probably resulted from debris from the Underground cloud.

Rock Springs, Wyoming, and Wendover, Utah, the remaining two stations for which data are available, showed increases in measured activity at times which are consistent with the available meteorological data.

For greater distances from the Test Site the areas where debris settled to the surface are shown in Appendix A (Figures A.43-A.46). These areas lie to the north of the trajectory of the top of the cloud, i.e. that part which crossed the divide. This displacement results from the winds in the levels below 10,000 feet. Figure 3.74 shows the primary cloud trajectory at the 700-mb level during the period from 0000 GCT 30 November 1951 through 0000 GCT 1 December 1951, the area at the surface considered contaminated by debris from the Underground cloud as of 1700 GCT 1 December 1951; and vectors showing the wind travel for the 24-hour period 1200 GCT 30 November to 1200 GCT 1 December 1951, based on the average wind from the surface to 10,000 feet at the station where the arrow originates. As this figure demonstrates, debris was carried by the lower level winds from the 700-mb level to the area of detection at the surface. The "tail" of the surface area of detection, extending to the Pacific Ocean over Medford and Eugene, Oregon, results from the effective downward transport of residual activity in the atmosphere by the heavy precipitation.

An eastward movement of the area of contamination at the surface was detected for only four days following the Underground test (Figures A.43 through A.46). Thereafter, occasional contamination was detected at isolated stations, but this detection occurred during periods of rainfall and cannot be directly attributed to the Underground cloud.

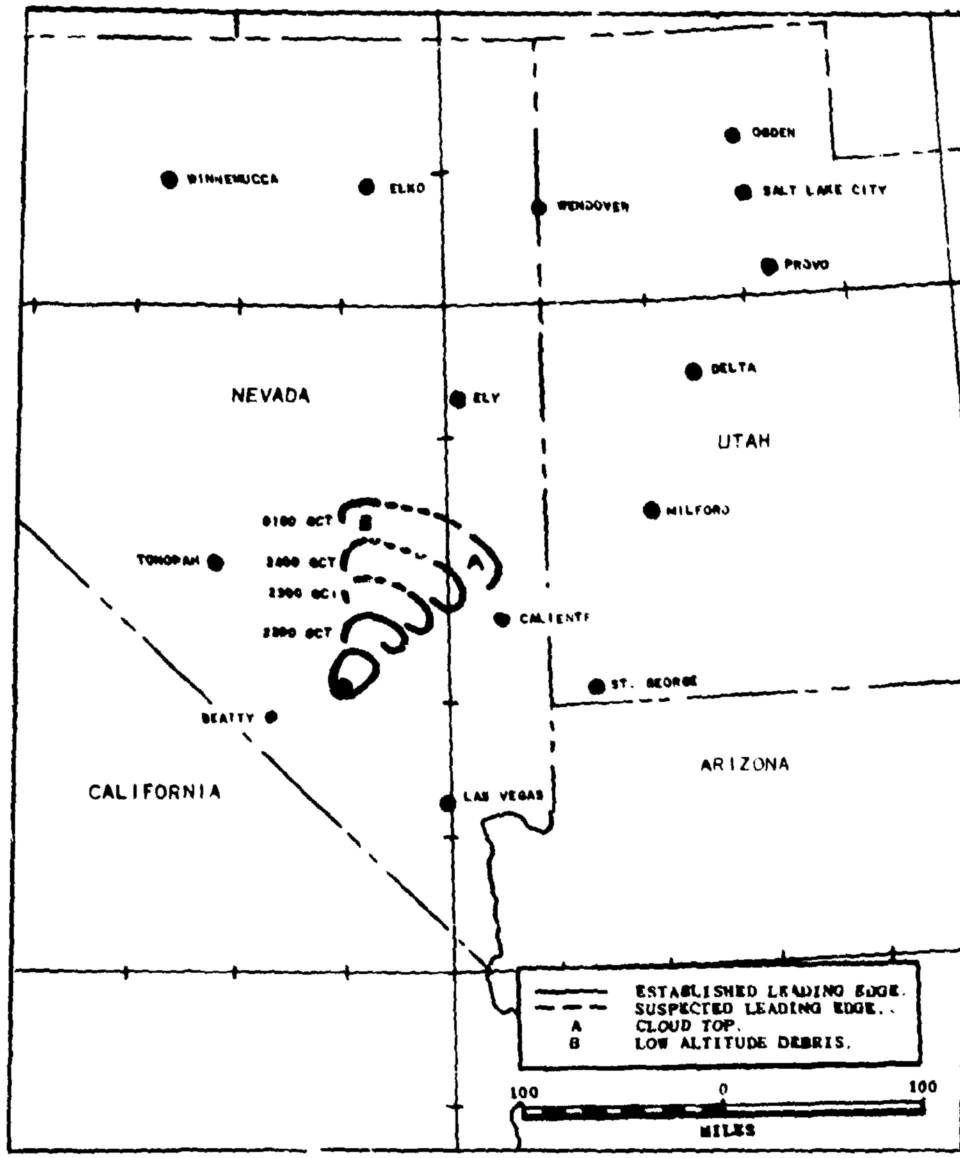


Fig. 3.62 Initial Movement of the JANGLE Underground Cloud. Detonation at 2000 GCT 29 November 1951; maximum height, 10,500 feet.

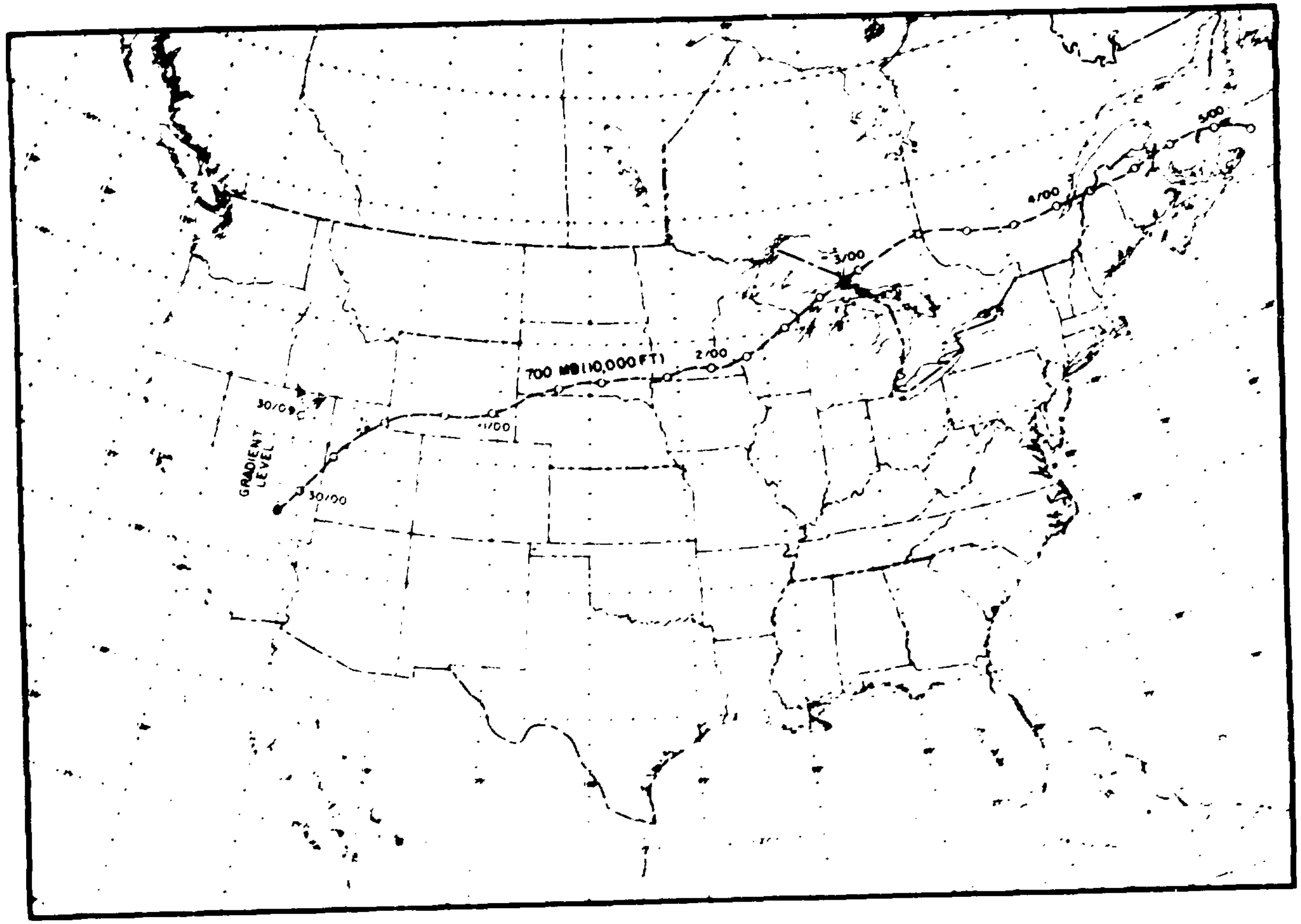


Fig. 3.63 Trajectories of the Primary Cloud from JANGLE Underground

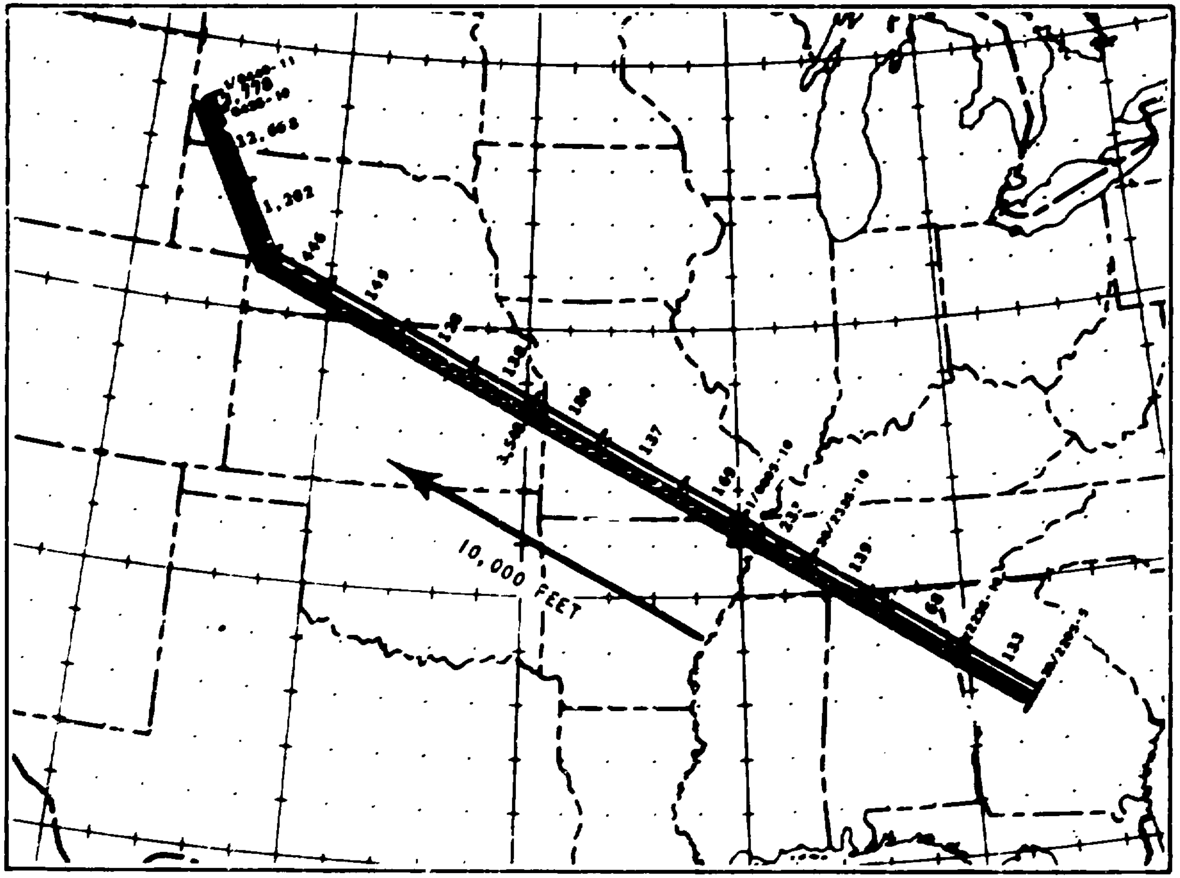


Fig. 3.64 LAKE WILLIAM 22, 30 November - 1 December 1951 - Outbound

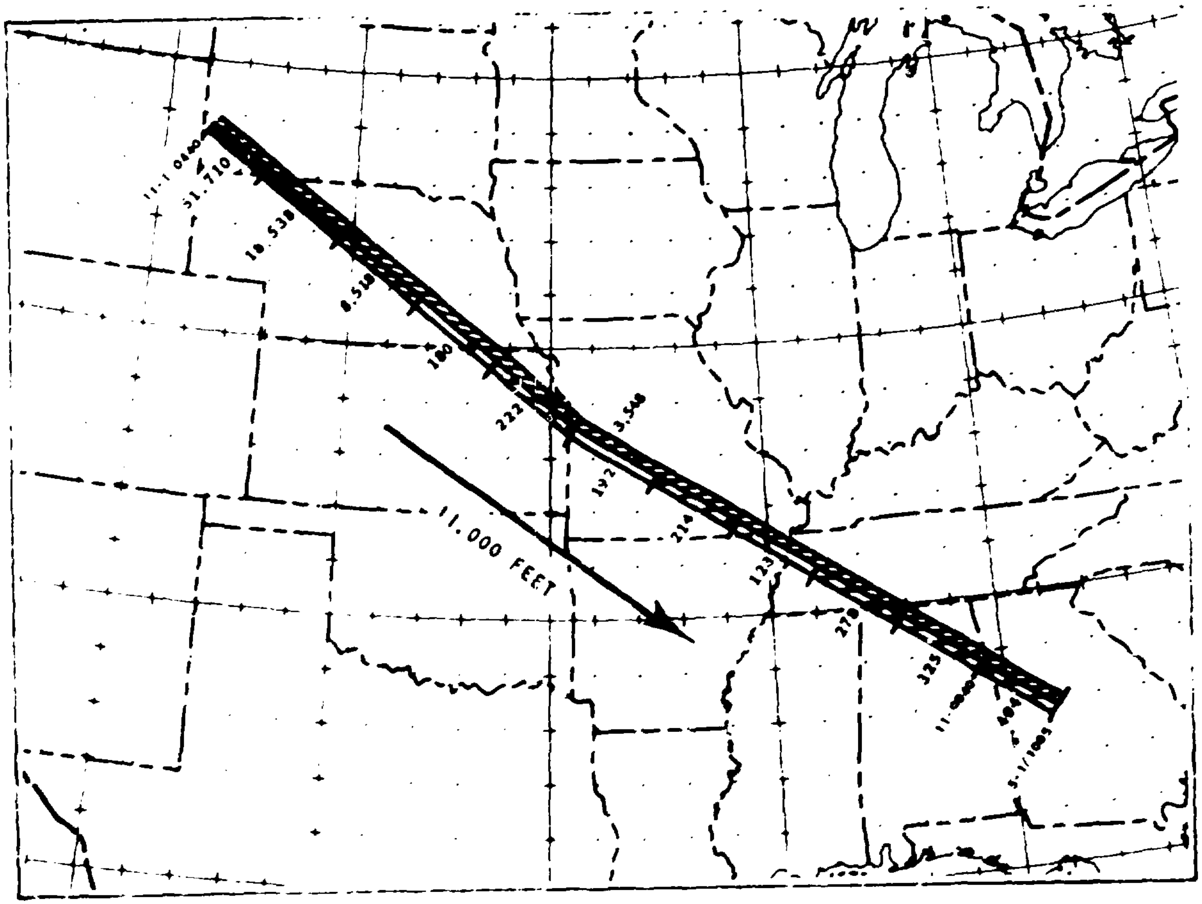


Fig. 3.65 LARK WILLIAM 22, 30 November - 1 December 1951 - Inbound

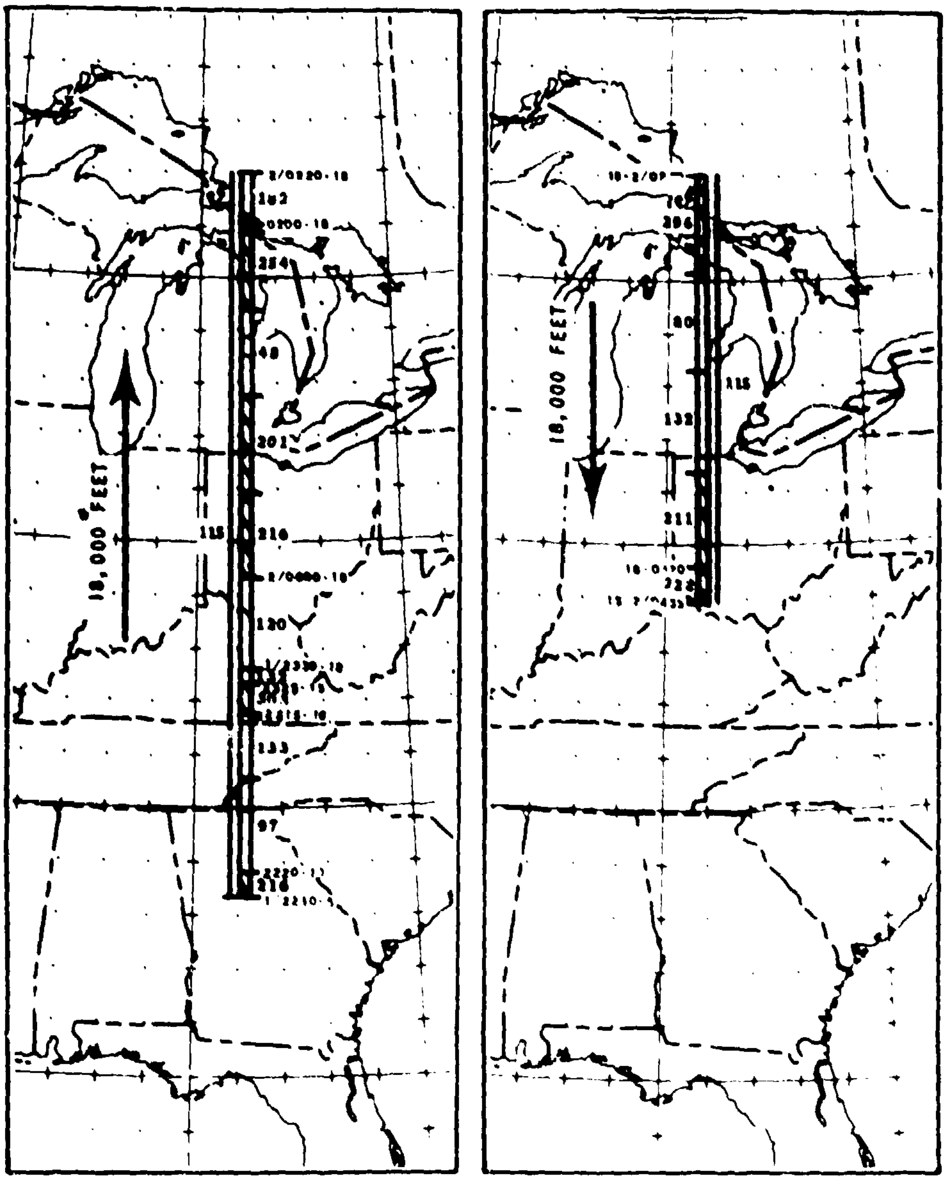


Fig. 3.66 LARK WILLIAM 23, 1-2 December 1951 - First Part

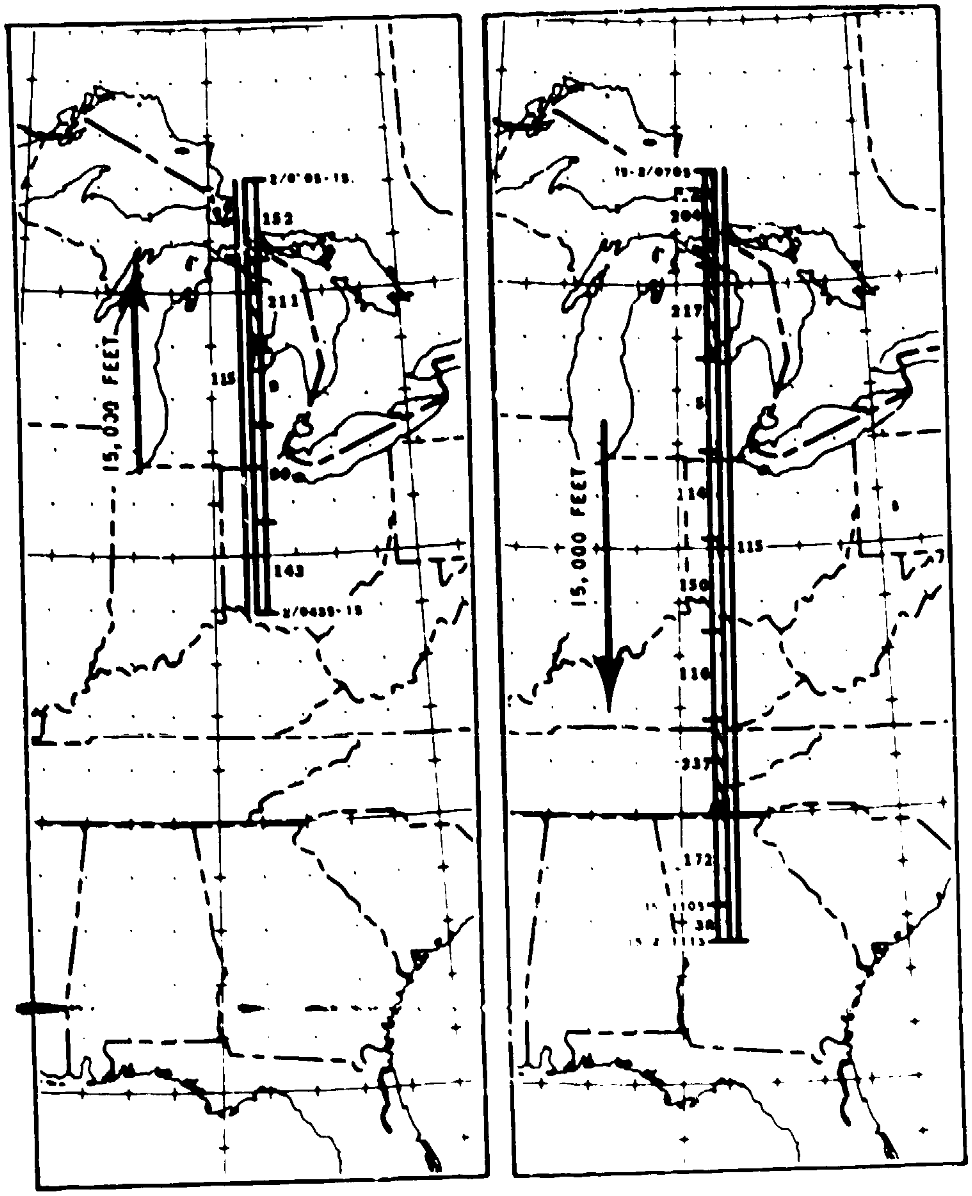


Fig. 3.67 LARK WILLIAM 23, 1-2 December 1951 - Second Part

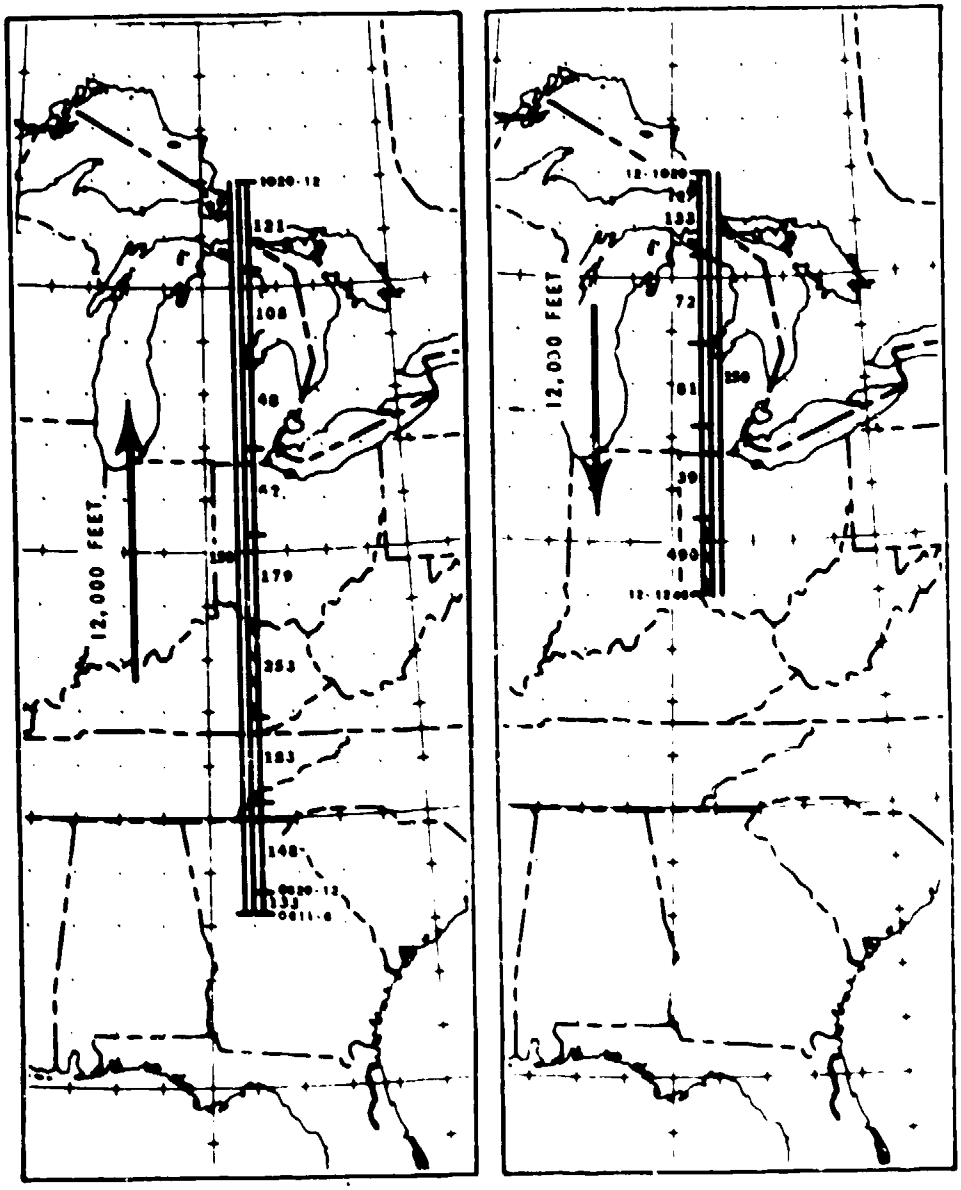


Fig. 3.68 LARK WILLIAM 24, 2 December 1951 - First Part

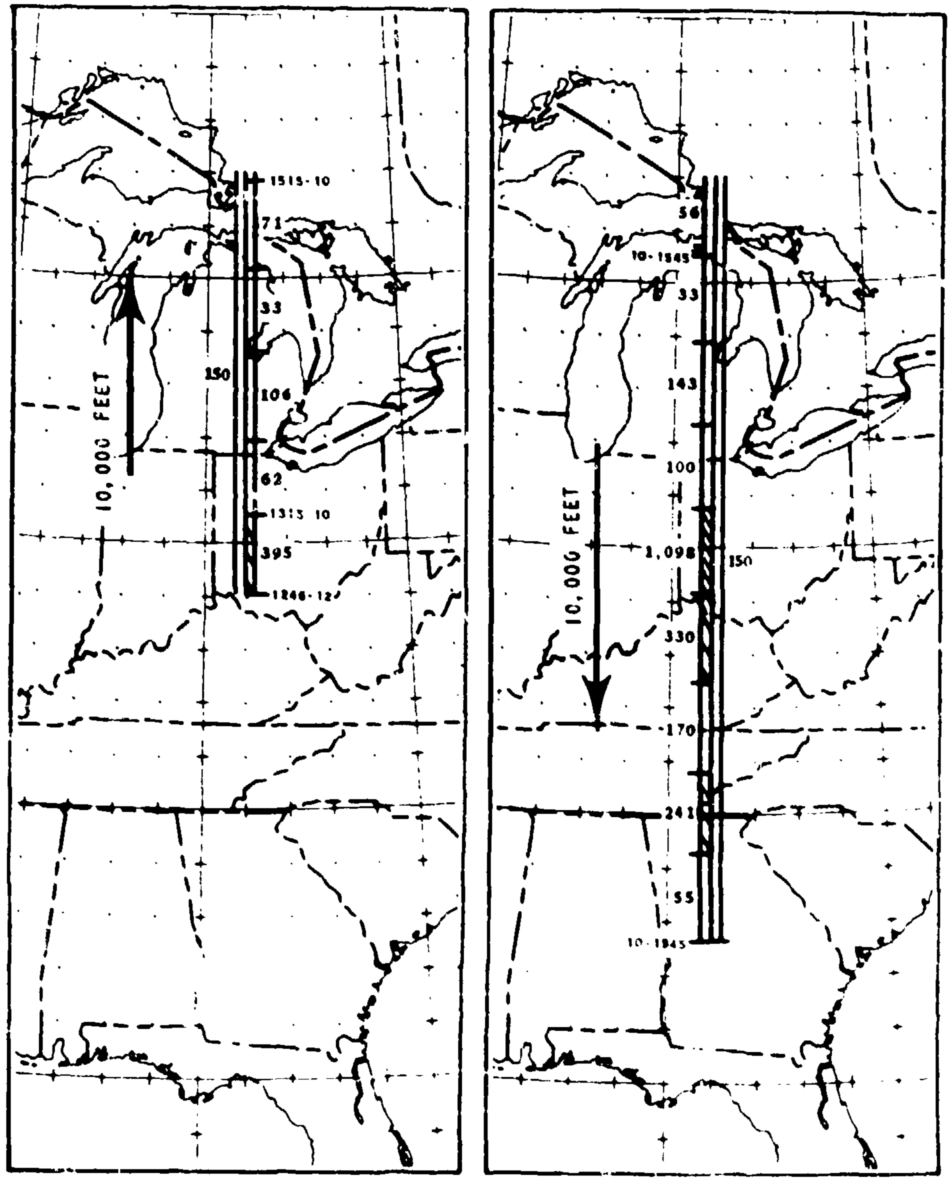


Fig. 3.69 LARK WILLIAM 24, 2 December 1951 - Second Part

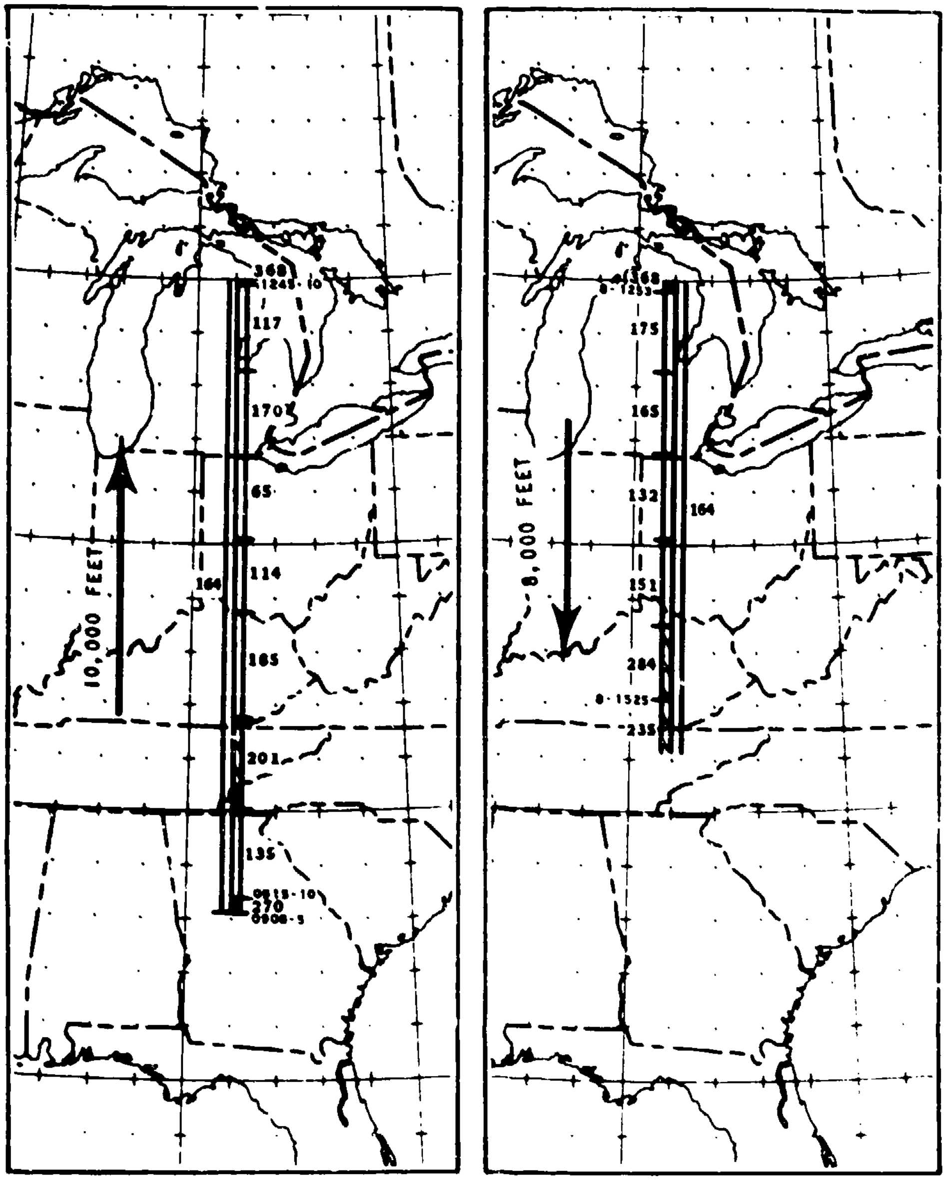


Fig. 3.70 LARK WILLIAM 25, 2 December 1951 - First Part

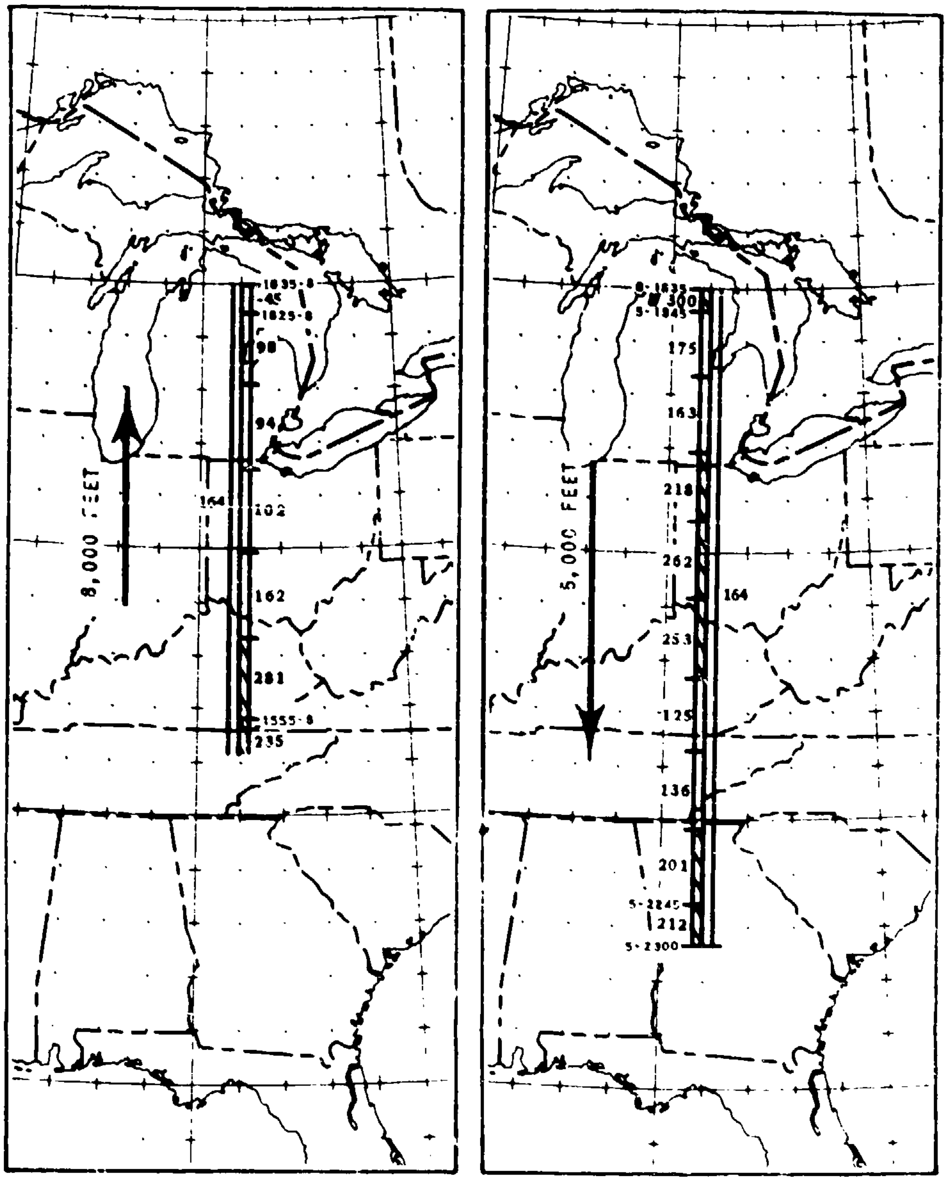


Fig. 3.71 LARK WILLIAM 25, 2 December 1951 - Second Part

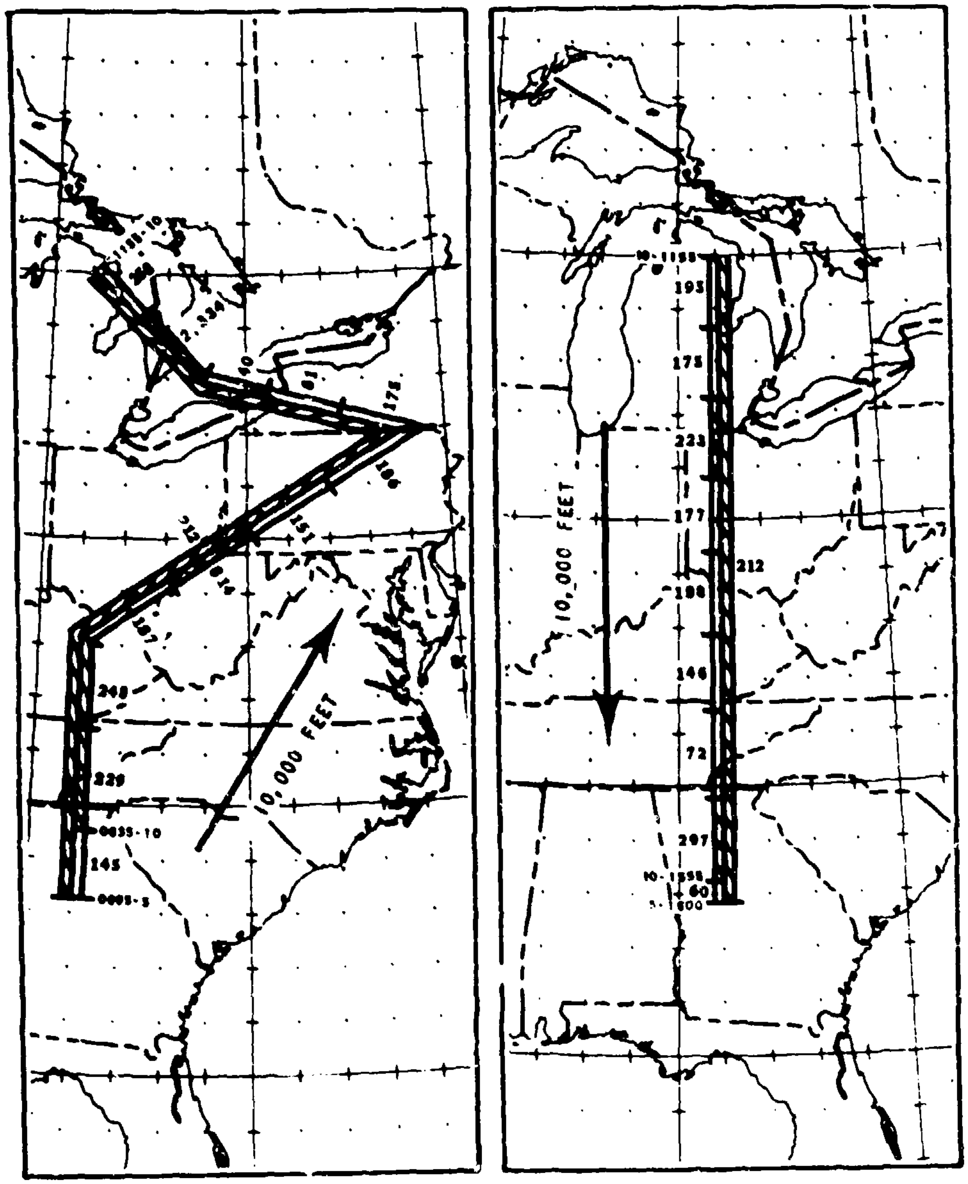


Fig. 3.72 LARK WILLIAM 26, 3 December 1951

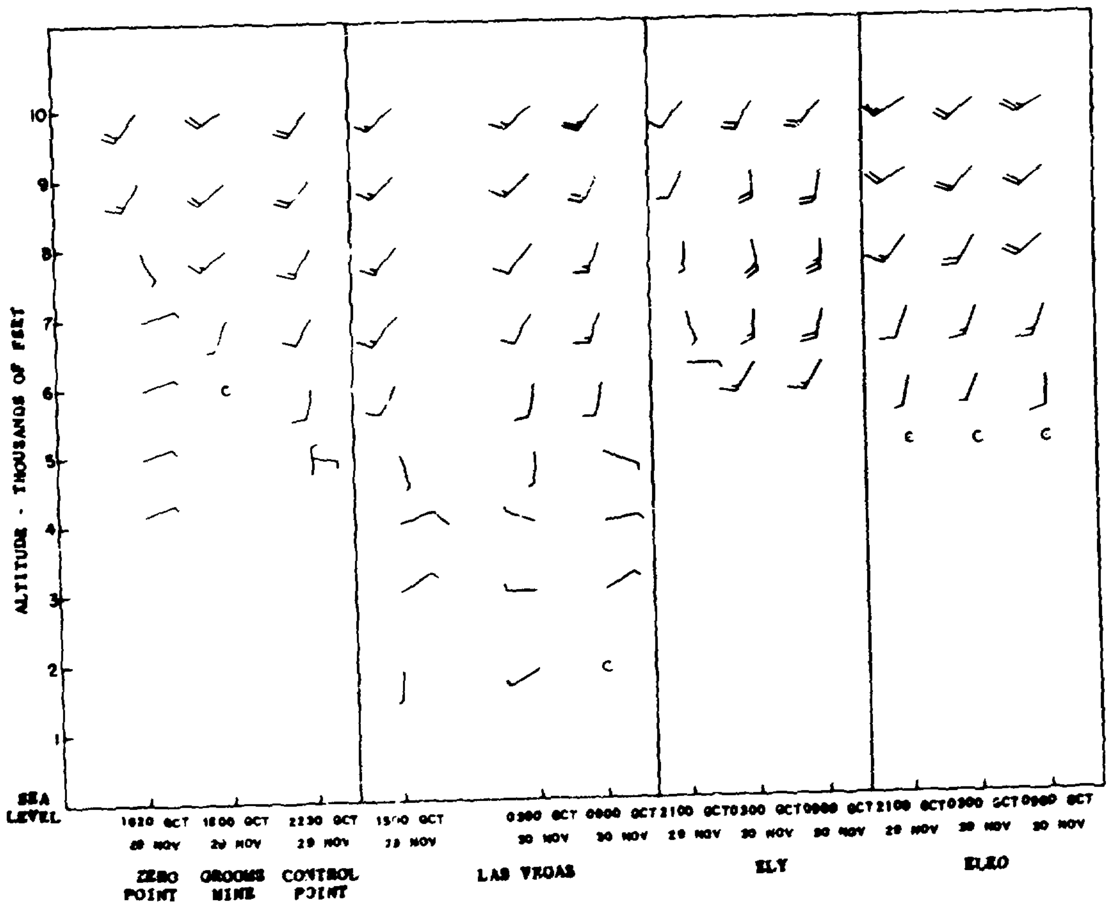


Fig. 3.73 Wind Observations for the Underground Burst

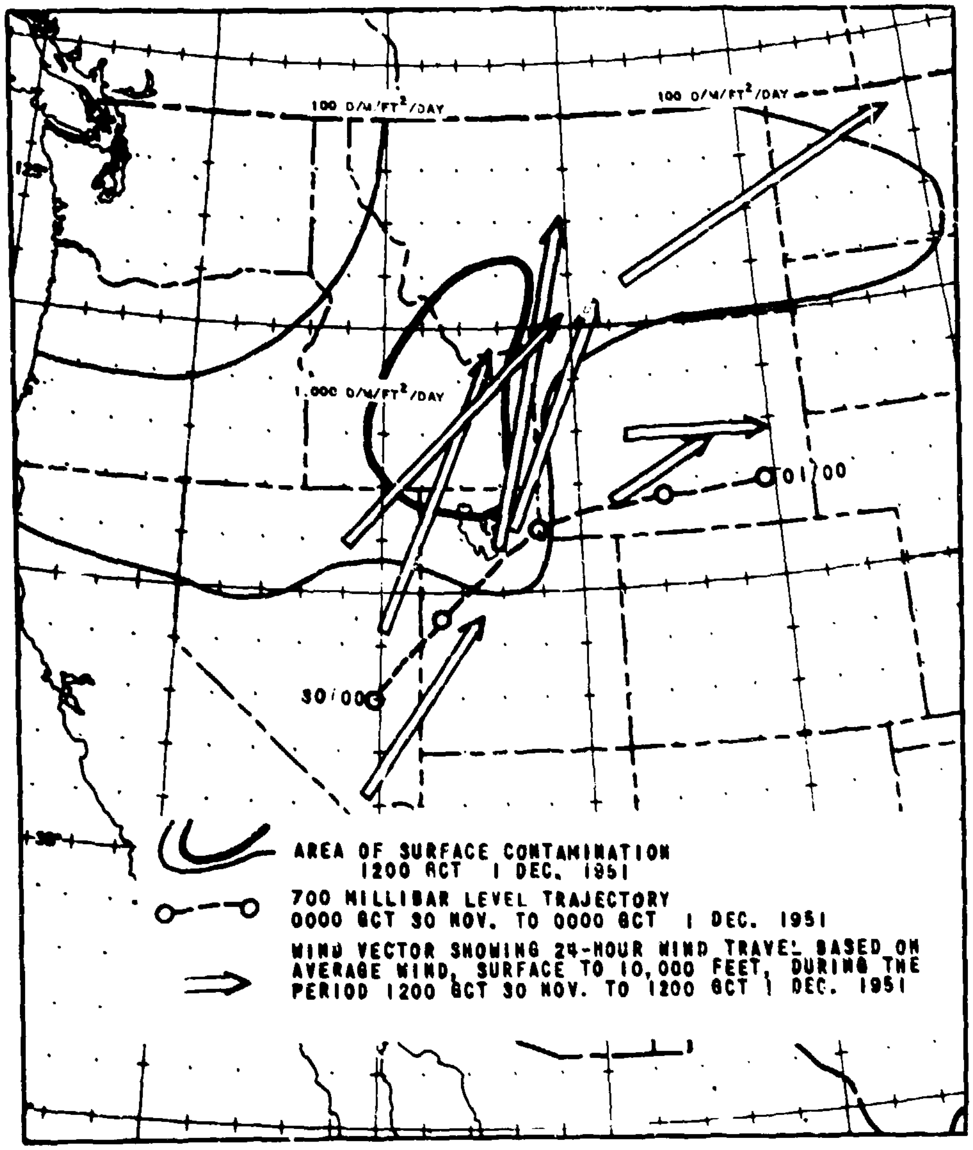


Fig. 3.74 Surface Contamination from the Underground Burst

CHAPTER 4

FALLOUT MONITORING AT THE GROUND

4.1 INTRODUCTION

The distribution of radioactive debris at the ground, or more particularly the distribution of debris collected by the monitoring devices, was discussed in part in Chapter 3. There are a number of general comments, however, which should be made about the techniques and results of the fallout-monitoring program.

4.2 THE EFFECT OF PRECIPITATION ON GROUND CONCENTRATIONS

The fact that rain or snow can scavenge particulate debris from the atmosphere has long been known. The measurements of radioactivity at the ground by the fallout-monitoring network provide additional evidence of this phenomenon, and it is possible to study the effect of precipitation on the three sampling devices.

4.2.1 Fallout Trays

The trays collect whatever debris falls in them in the absence of rain and also whatever material is brought down by the rain. Thus, the tray measurements are especially sensitive to rain-out. This is readily apparent from the parallelism between areas of high activity, based primarily on data from the trays, and, of areas of precipitation, as seen in the figures of Appendix A.

A particularly good example of this parallelism is seen in Figures A.4 - A.12 in connection with the movement across the United States of debris from the third Russian burst. The first appearance at the ground of material from this burst occurred in the State of Washington on 22 October 1951 (Figure A.4) and it can be seen that the observed activity coincided almost exactly with the precipitation area. On the 23rd (Figure A.5) the same coincidence occurred in the northwest, and a region of increased activity appeared in Illinois - again in an area of precipitation. This same phenomenon was also evident on the six succeeding days. On the 23rd and 24th, the absence of activity over the Plains States, where no precipitation occurred is a striking confirmation of the importance of precipitation in bringing debris to the ground.

There was a highly significant difference in the activity found on the trays in periods of no precipitation and in periods with precipitation. About a tenfold increase in activity was found to occur during periods with over 0.10 inch of precipitation as compared with periods having no precipitation.

In general, the wet tray provided a fairly large area for catching particles, and it provided a means of sampling precipitation as well - thus serving as a measure of the radioactivity that would reach the ground. However, for several reasons, the data from the tray station were subject to errors. In the first place, if the tray dried out - as could occur in a few hours on a dry, windy day - all the debris which fell on the tray might not have stayed there. Also, there is always the chance that some of the water in the tray was spilled with a resulting diminished count. The most serious fault of the tray, however, was that some of the sample was frequently lost as a result of overflowing in rain. An overflow on the tray was designed to collect surplus water in a two-quart jar, but rain falling on a surface of nearly 9 square feet would quickly fill the overflow jar. For example, if the tray was initially full of water it would take only about 0.10 inch of rain to fill the jar, and there were often large sections of the country with more than an inch of rain in a day during the period of the tests. The observers at the weather station often did not have time to service the trays every few hours as would be required on certain days.

The difficulties in tending the trays and the frequent unreliable measurements that resulted have led to the abandonment of the tray as a collection device for future tests.

4.2.2 Gummed Paper

Like the tray, the gummed paper collects debris actually deposited on a horizontal surface. The characteristics of the gummed paper are not fully known. For example, the effect of temperature and humidity on the stickiness has not been investigated. At low temperature the surface may not hold all of the particles that strike it. Snow may cover the paper and prevent the adhesive qualities from acting effectively. Also, the amount of debris carried away in rain-water which runs or spatters off the surface is not known.

Preliminary studies of data from several stations equipped with both tray and gummed paper have shown that there was a significant positive correlation between the activity collected by the tray and by the gummed paper; that on the average the gummed paper was a more efficient collector than the tray, and, further, that in periods of precipitation the gummed paper indicated proportionately higher activity than the trays.

As a result of its greater collecting efficiency and simpler operation, the gummed paper has been chosen as the measuring device for radioactivity deposited on a horizontal surface in future tests.

4.2.3 Air Filter

The air filter collects particles suspended in, or falling through, the air rather than those deposited on a horizontal surface and hence would be expected to give different results. The air-filtering device was sheltered so that snow or raindrops normally did not impinge upon the filter; debris contained in the precipitation was thus not collected.*

A comparison of concentrations reported by air-filter stations showed that there was a statistically insignificant variation between periods of precipitation and no precipitation. In the cases studied, the precipitation was of the widespread, warm-frontal type rather than of the shower or thunderstorm variety. These results, when considered with the marked increase in activity measured by trays and gummed paper in precipitation, can be interpreted as indicating that in steady rain, at least, debris is almost entirely brought down by the droplets rather than in the air surrounding the drops. The effect of showery precipitation and the correspondingly greater vertical motions of the air on air filter measurements remains to be determined.

4.3 VARIABILITY OF RADIOACTIVITY MEASURED AT THE GROUND

A cursory inspection of the results of the fallout-monitoring program contained in Appendix A reveals large variations in reported activity from station to station. It is important to know what causes such variations.

4.3.1 Observations by Same Method

In addition to the variation from station to station during a given period, there are great fluctuations with time of observations of the same type at a particular station. Even when two trays were placed side by side, they often gave very different results during the

---

* Occasionally, in heavy rain, the water did get to the filter, in which cases the filter frequently burst and the sample was lost.

same period.[10] The greatest variations are associated with precipitation but significant anomalous variations occur even on days without precipitation. Several causes for these anomalies can be suggested. Slight differences in exposure, for example, height above the ground, nature of the local terrain, or proximity to obstructions which might produce local eddies, could have a marked effect on the amount of debris collected. The deposition of a few very active particles might also affect one sample and not the other. The care in handling the collecting equipment, especially the trays, is also important. The local wind speed and direction can also cause one station to receive much higher concentrations than nearby stations as, for instance, when debris once deposited on the ground is redeposited by local wind action.

Before the variability can be completely understood, work must be done to determine the exact effects of exposure, microturbulence, and the local wind field.

4.3.2 Observations by Different Equipment

Still greater confusion in the interpretation of measurements of ground contamination results from the very different results obtained by two sampling methods which are supposed to measure the same quantity. The tray and gummed paper samples were correlated, to be sure, but the scatter around the regression line was very large.[11] The tray and the air filter, of course, do not measure the same quantity, but would be expected to show parallel results. Yet many times, even in the absence of precipitation, these two devices indicate opposite trends in the activity.

The specific causes of such anomalous behavior will not be known until the various effects involved are better understood.

4.3.3 The Significance of the Variability

The great variability in the reported ground concentrations of radioactivity in both time and space is due both to real differences in transport and to fictitious differences introduced by sampling procedures. The uncertainty in the sampling procedures stems from two

---

10 *ibid.* Page 69 and Appendix H

11 *ibid.* Pages 70, 71

sources: first, the difficulty in making the observations carefully and, second, the variable collection efficiency under various atmospheric conditions. While it is true that the data from the trays and gummed paper are measures of the activity falling to the ground, there is no way of knowing what the exact relationship might be. The uncertainty in the reliability and meaning of the tray and gummed paper results precludes any satisfactory quantitative fallout or rainout study at this time.

4.4 EXTREMES OF GROUND CONTAMINATION

Even with the many observations at the ground and from aircraft during the BUSTER and JANGLE tests, it was not possible to come to any definite conclusion as to the contaminations to be expected under given conditions and at specified distances from the origin of the burst. However, the observed concentrations at the ground gave a rough idea as to what maximum concentrations might occur under test conditions similar to those of BUSTER and JANGLE.

4.4.1 Extreme Air Filter Measurements

The highest air-filter measurements outside the test area, up to 4×10^5 d/m/meter^3, were, logically enough, at Elko, Nevada[12] only 200 miles from the Site. These resulted from the JANGLE bursts, which did not distribute their debris to great heights as did the larger weapons. East of the mountains, high values were found by the mobile monitoring teams in Texas approximately 800 d/m/meter^3 on 5 November.[13] The highest value along the 84th meridian was that at Cincinnati on 1 November - 570 d/m/meter^3.

These extreme values are of the same order of magnitude as the higher counts observed with aircraft filters.

4.4.2 Extreme Deposited Activity

The highest activity, 360,000 d/m/foot^2/day, observed by tray or gummed paper was that of the tray at Rochester on 1 November. Moreover, Rochester had the greatest cumulative amount of any station.

---

12 ibid, Fig. 10

13 ibid, Appendix B

There is a reasonable explanation for the high activity occurring in this part of the country. Several of the clouds from the burst passed over the Northeast during persistent rains there. Rochester is very favorably located to receive frequent precipitation, with large lakes both to the north and west, and large quantities of rain and snow fell there during the period of the tests. This does not explain, however, why Rochester had so much more radioactivity than, say, Cleveland or Binghamton. The explanation of this is not known. One can only suppose that such effects as exposure, local winds, and in particular the care with which the samples were collected, were favorable for high counts.

4.4.3 Maximum Possible Hazard

The maximum possible deposition of radioactivity at the ground is a function of the quantity and nature of radioactivity in the cloud, the vertical distribution of the debris, the amount of diffusion, and the effectiveness of the mode of downward transport. It has been shown that rain is exceedingly effective as a means of producing the downward transport. One may, therefore, conceive of a combination of conditions which would readily create dangerous activity at the ground. For example, rain which occurs in and over a newly formed atomic cloud might wash down a very large fraction of the debris to the ground and produce a major hazard.

A second potential source of high radioactivity at the ground, one that has received little attention, is a low-level cloud which reaches an inhabited area before adequate dilution takes place. The relatively high activity at Elko, Nevada, following the Surface and Underground bursts illustrates the potential of such low-level transport. If all the active debris were beneath a strong temperature inversion through which little diffusion is possible, one might find surprisingly high values at points remote from the Site. It would be worthwhile to track the lower portions of clouds to ascertain more properly the degree of activity at these elevations.

While the tests carried out at Nevada have not produced any serious hazard at places removed from the Site area, these bursts have occurred under conditions selected to prevent such hazard. It is felt that such caution should continue to be exercised in the future since evidence collected during BUSTER and JANGLE indicates a potential danger.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 DETECTION OF FOREIGN EXPLOSIONS

The studies of the BUSTER and JANGLE operations have brought to light several important factors which may affect the operating procedures of the 1009th Special Weapons Squadron for detecting and collecting debris from foreign atomic explosions.

5.1.1 Difficulties in Detecting Certain Radioactive Clouds

All debris at 25,000 feet from the Dog burst passed the 84th meridian during a period of no more than 10 hours, and even at the 500-mb level the time for passage of debris was probably less than 20 hours. This means that routine 500-mb flights at 48- or even 24-hour intervals could well fail to detect such a cloud at a distance of 1500 nautical miles from the source of the burst. Since this cloud was associated with relatively strong winds which exhibited little directional shear, it may be advisable to schedule more frequent flights during such meteorological conditions if a detonation is suspected.

In general, flights as close as possible to a suspected foreign test site are preferable if prompt detection and large young samples of debris are desired, but it is advisable to back up such operations with routine flights at greater distances from the suspected source. This would allow opportunity for greater elongation, lateral spread, and vertical extension of the cloud, thereby increasing the probability of detection.

5.1.2 Forecasting the Movement of Clouds

Another significant point is the lack of success of meteorological forecasts of cloud trajectories under some circumstances. Even over a region with relatively dense, reliable and promptly available upper-air meteorological data, it is not always possible to accurately forecast the path of the debris.

A notable example was JANGLE Underground (3.7.3). In an attempt to delineate the cloud rather than to insure detection, four flights were scheduled, each to make several traverses across the expected path of the debris. The original forecast was in error, and the cloud passed to the north of the area covered by the detection flights. Had a maximum range flight been dispatched from Robins Air Force Base toward the north, the cloud might have been intercepted. This case points out the hazard of restricting detection operations to a small area on the basis of meteorological forecasts. Flights should be planned with a sufficient margin in their coverage to allow for considerable meteorological error.

5.1.3 Identification of Debris

The experience with Baker and Charlie demonstrated the difficulties which may be encountered in distinguishing, meteorologically, debris from a series of consecutive bursts, even though separated by one or more days in time. Although Baker and Charlie were detonated two days apart, debris from the two clouds arrived at the 84th meridian within 12 hours of each other, since the Charlie cloud attained a higher altitude, was carried by faster winds, and took a more direct path to the flight line than the Baker debris.

This uncertainty exists to an even greater extent in connection with debris collected by the surface monitoring network. Although this network is capable of collecting large quantities of debris from the bursts, the association of a sample obtained at the ground with a particular burst frequently is not possible. This results from the fact that material from successive bursts, moving in different wind fields, can become mixed by the processes of diffusion, fallout, and precipitation.

5.1.4 Operational Facilities

When special aircraft flights are contemplated for the precise delineation of a cloud of debris, particularly when the timing of the flights is critical, it is advantageous to have the meteorological office from which trajectory forecasts are to be made, located at the airbase from which the flights are to be made. Such an arrangement eliminates the unavoidable communication delays and permits a more rapid alteration of plans when additional meteorological information is received.

5.2 GROUND CONTAMINATION

5.2.1 The Effect of Precipitation on Surface Contamination

Precipitation is the dominant cause of deposition of high concentrations of radioactive debris on the ground away from the test area. A real hazard to personnel might exist as much as several hundred miles from the site of a burst if rain occurred in the region of most concentrated radioactivity.

By far the greater part of the debris deposited by precipitation during the BUSTER and JANGLE tests was carried downward in raindrops. Whether the debris came primarily from the cloud layer where the raindrops originated, or whether it was collected from the air through which the rain fell, has still to be determined. Concentrations in the air at the surface were not changed significantly during periods of rain. This effect should be investigated not only in general rain areas but also in showery types of rain, which occur more frequently in spring and summer.

5.2.2 Variability of Measured Concentrations

Variations in the measured concentrations at the ground were large and frequent, and in many cases could not be adequately explained. Consequently, the exact meaning of the results of the surface-monitoring program is not known. Research should be undertaken to determine what specific meteorological and other factors cause these variations.

5.2.3 Channeling of Low-Level Debris

The channeling of the cloud by the terrain near the Test Site was very effective, as shown by the high counts measured at Elko, Nevada, after both JANGLE bursts. Under certain conditions, even higher concentrations might exist through a layer several thousand feet thick and, with precipitation, could produce a real hazard to personnel on the ground. For future tests it is recommended that the lower part of the cloud, which might be channeled by the terrain, be tracked and that the thickness of this portion of the cloud be determined, in order that the possibility of hazard to personnel may be evaluated. Additional wind observations should be obtained in those regions near the site where no permanent stations exist and through which the debris may be channeled.

APPENDIX A

DATA FROM THE FALLOUT-MONITORING NETWORK

This appendix gives the data obtained from the fallout-monitoring network established by the New York Operations Office of the AEC. The general nature of the network and the sampling techniques were presented in Chapter 2 of the basic report and are also covered in the report of the New York Operations Office.[1] Locations of the stations are given in Figure A.1, along with the midtime (GCT) of the sampling period at each station and the model used in recording the data on the maps.

The beginning time of the sampling period was determined largely by the work load at each station and hence differed from station to station. At any one station, however, the sampling period began at about the same time each day. All samples which included 1800 GCT on a given date are recorded on the map for that date.

The amount of precipitation which occurred during the sampling period is given, in inches, below the station circle. These precipitation amounts were obtained in most cases from the STATION METEOROLOGICAL SUMMARY (Weather Bureau Form 1001 C). Generally these forms give the hourly amounts of precipitation, so that the amount which fell in any 24-hour period could be approximated closely. In some cases the amounts recorded are for a different Weather Bureau station in the same city, or were obtained from the six-hourly surface observations. Snow has been reduced to its water equivalent.

The shading shows areas where 0.01 inch of precipitation or more occurred during the sampling period. Between the sampling stations the areas are only approximate.

The radiological data are essentially those included in Appendix A of the New York Operations Office report (distribution of this appendix is very limited) except that samples extending over two or more days have been omitted. For 22 October and succeeding days, all data were extrapolated to the sampling date by the New York Operations

---

[1] U.S. Atomic Energy Commission, New York Operations Office, Radioactive Debris from Operations BUSTER and JANGLE: Observations Beyond 200 Miles from the Test Site, NYO-1576, 28 Jan 1952 (SECRET)

Office, on the basis of an assumed rate of decay and the particular burst assumed to have been represented. The rate of decay assumed ($t^{-1.2}$) is only approximate; and, more significant, the meteorological analysis indicated that debris had been attributed to the wrong burst in many cases. As a result, the extrapolated concentrations recorded are often in error by as much as a factor of two. Considering the great variability of the concentrations, this is an insignificant error.

The isolines show the approximate areas of contamination throughout the United States. The dashed and solid lines represent, respectively, the 100 and 1,000 d/m/foot^2/day concentrations from the trays, but were also drawn for the roughly equivalent values from the gummed paper - 400 and 3,500 d/m/foot^2/day - where the tray values seemed unrepresentative.

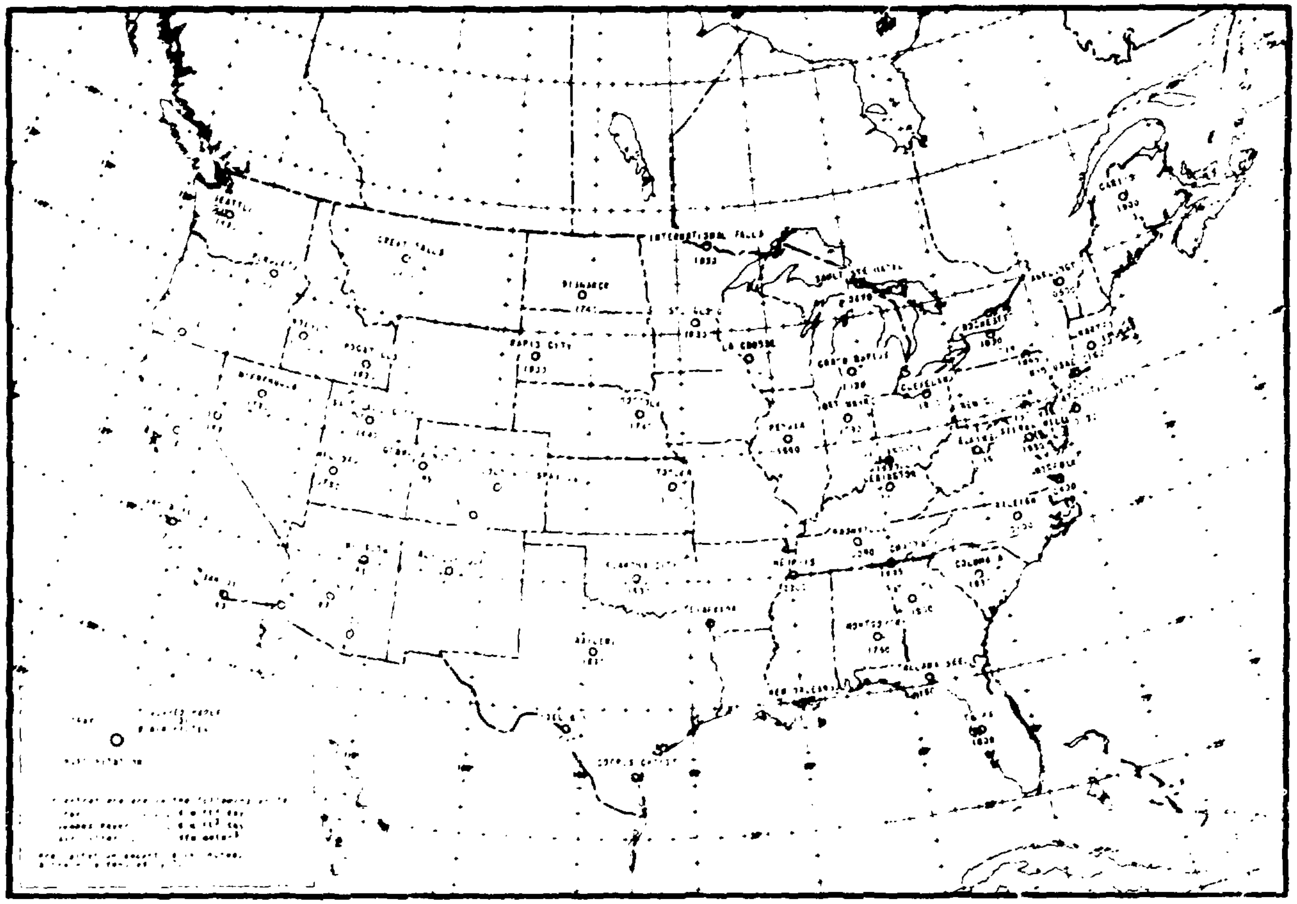


Fig. A.1 Fallout-Monitoring Network. Midtime (GCT of sampling period is shown beneath station circle. Plotting model for surface distribution maps is given in inset.

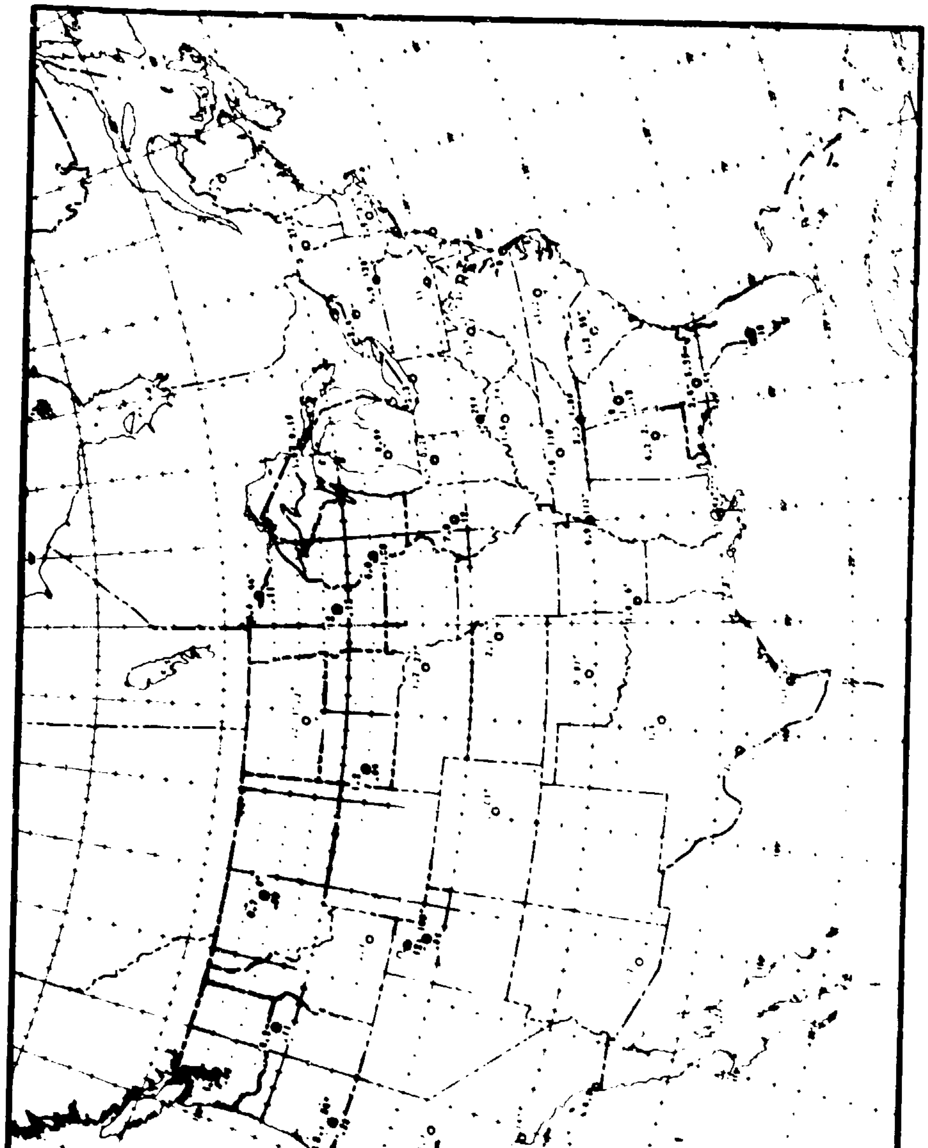


Fig. A.2 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 20 October 1951

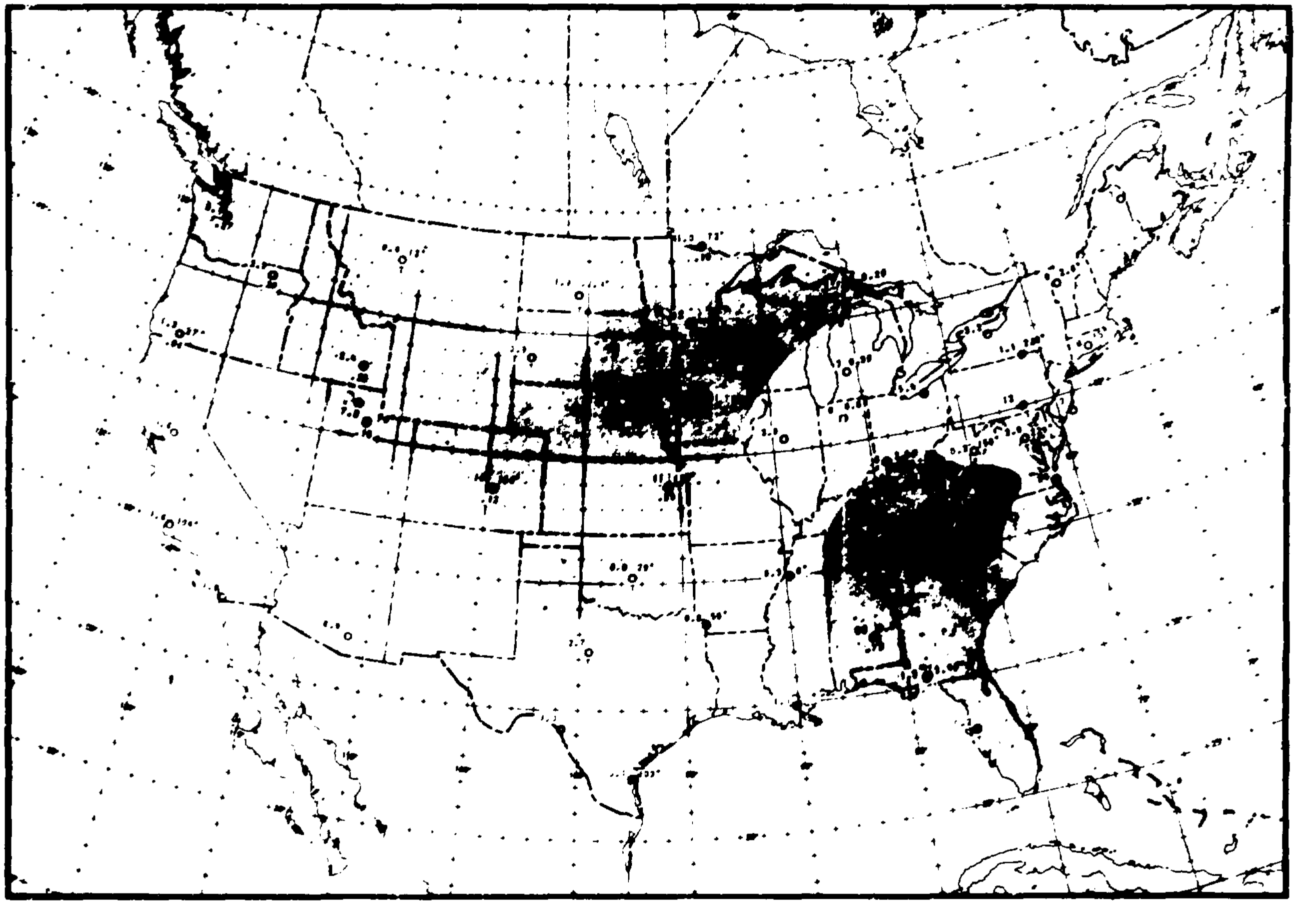


Fig. A.3 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 21 October 1951

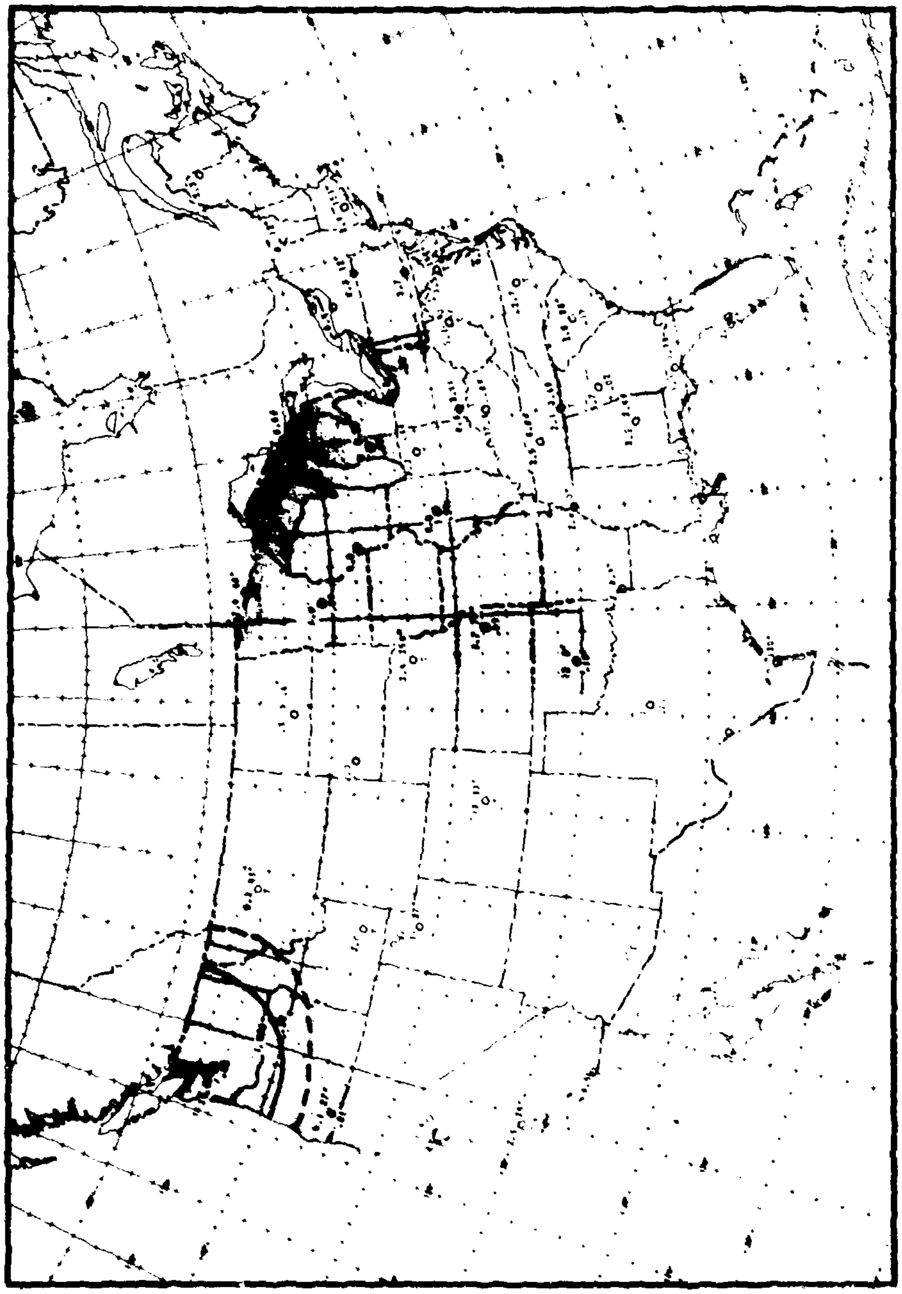


Fig. A.4 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 22 October 1951

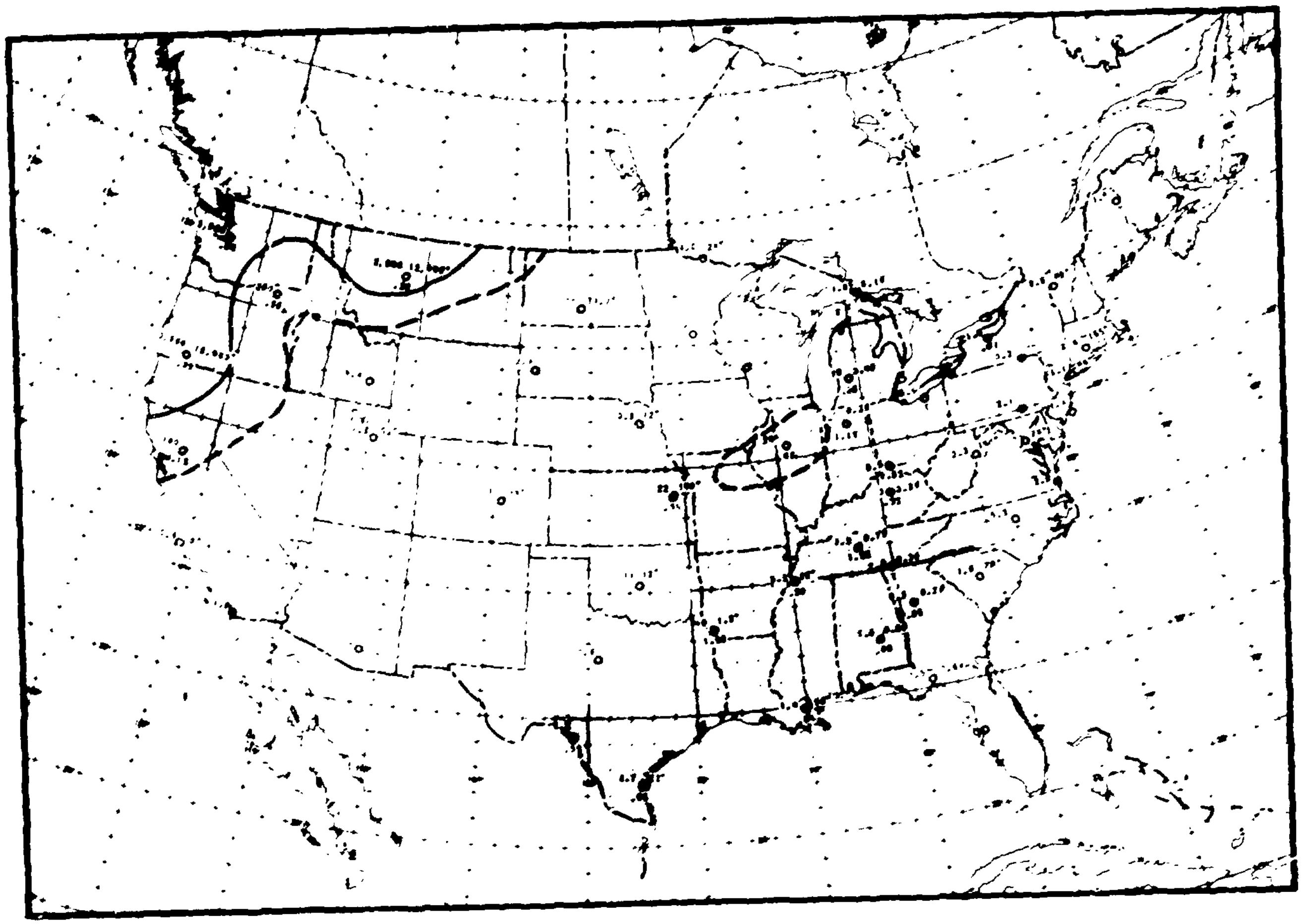


Fig. A.5 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 23 October 1951

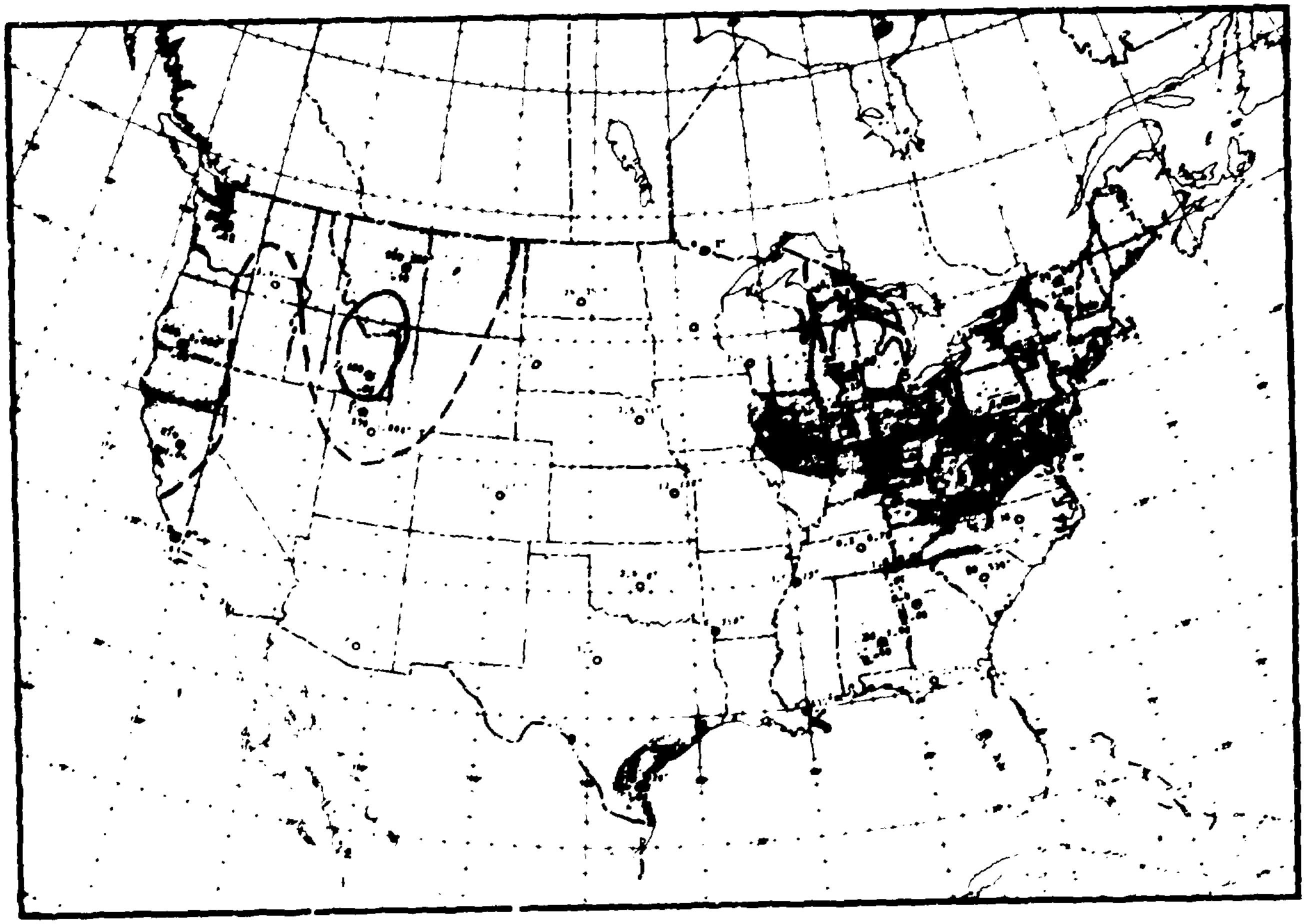


Fig. A.6 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 24 October 1951

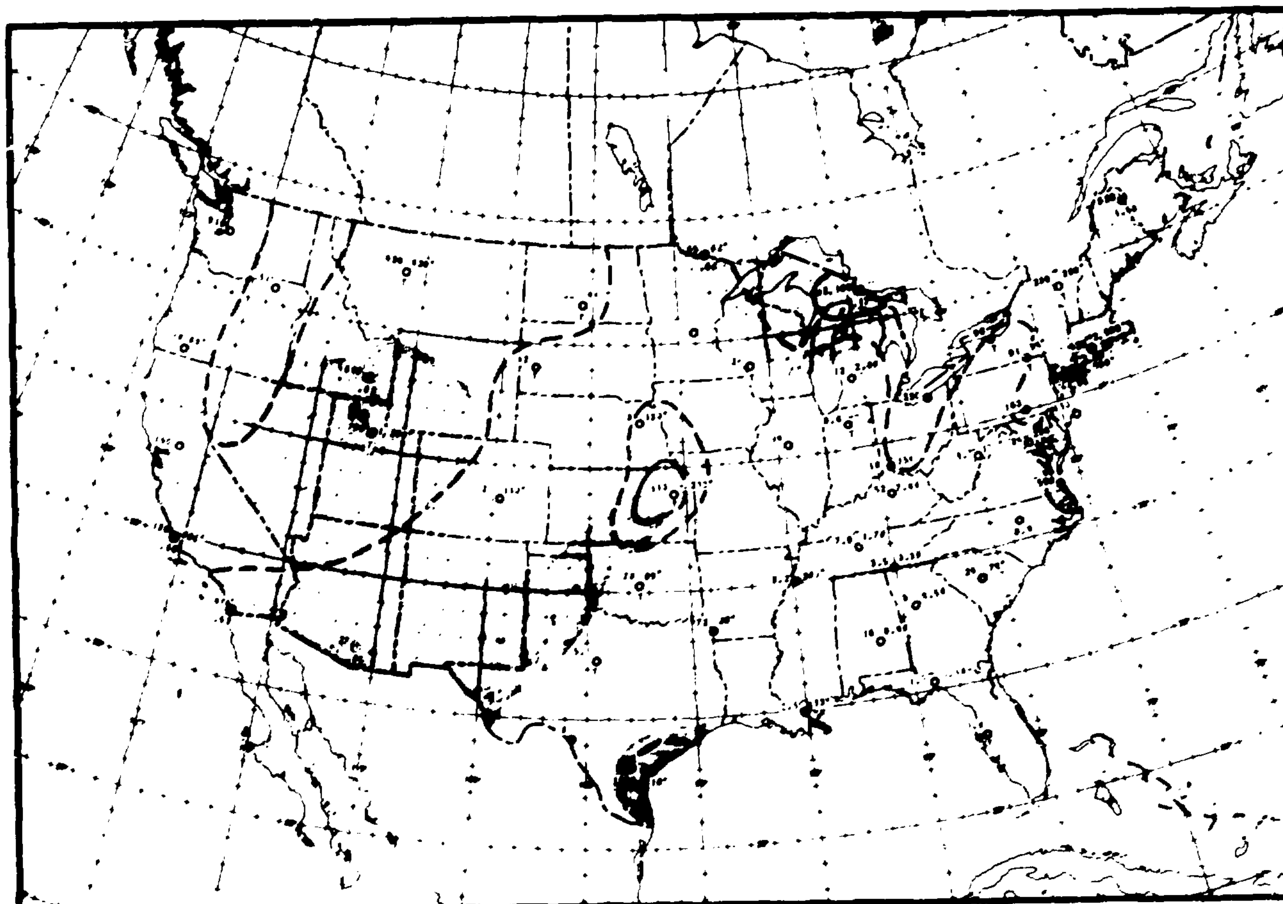


Fig. A.7 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 25 October 1952

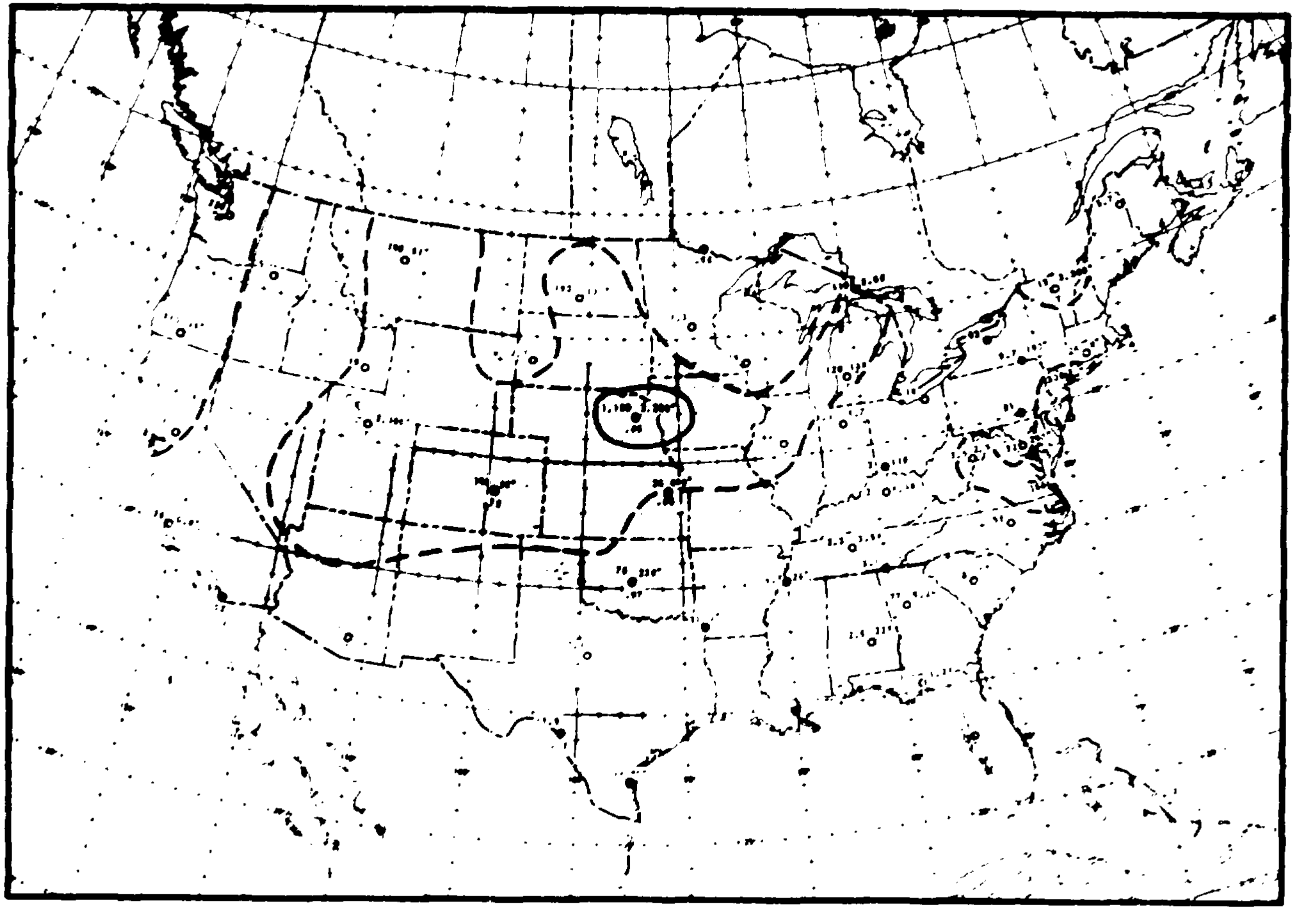


Fig. A.8 Surface Distribution of Radioactive Detris and Concurrent Precipitation, 26 October 1951

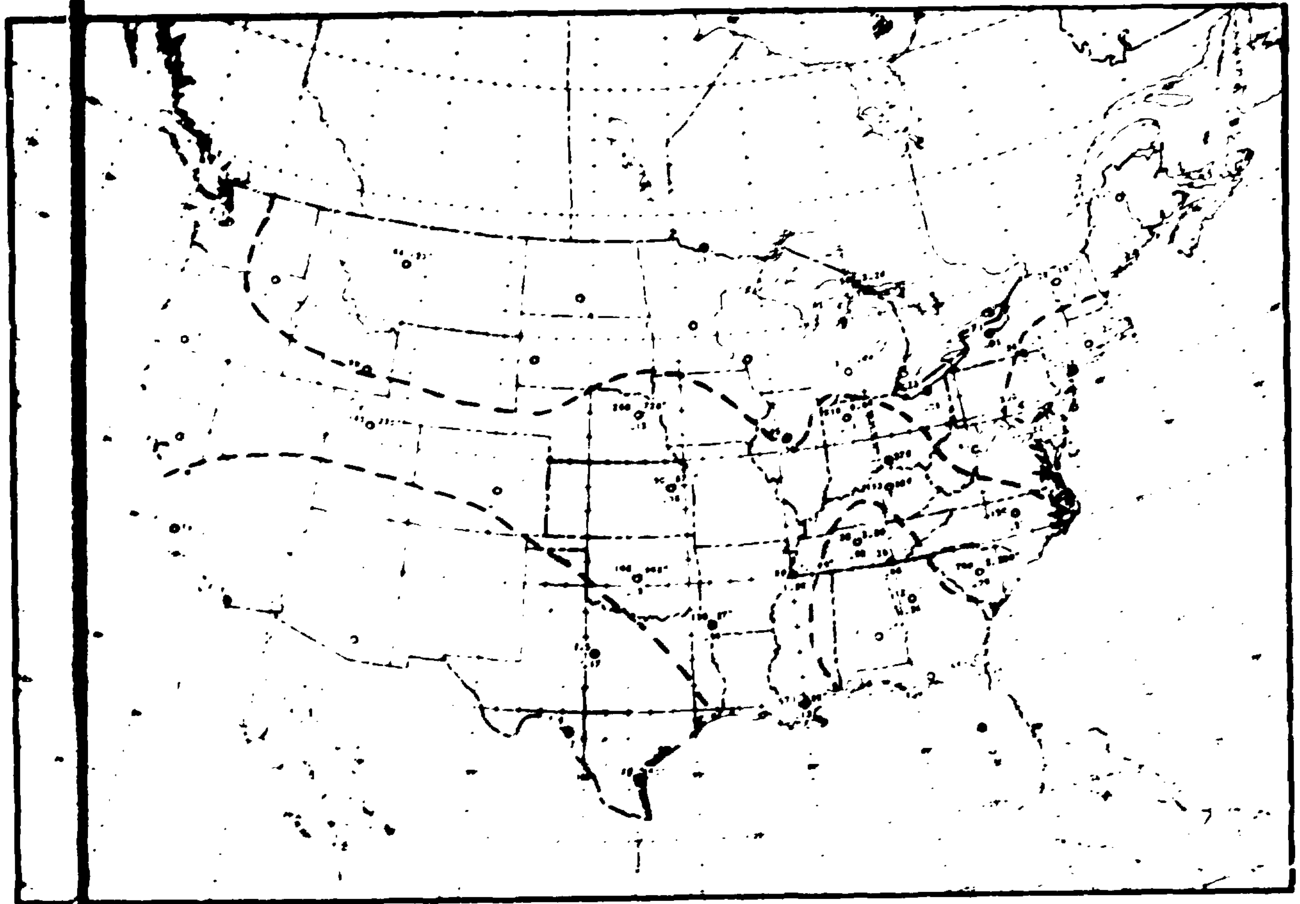


Fig. A.9 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 27 October 1951

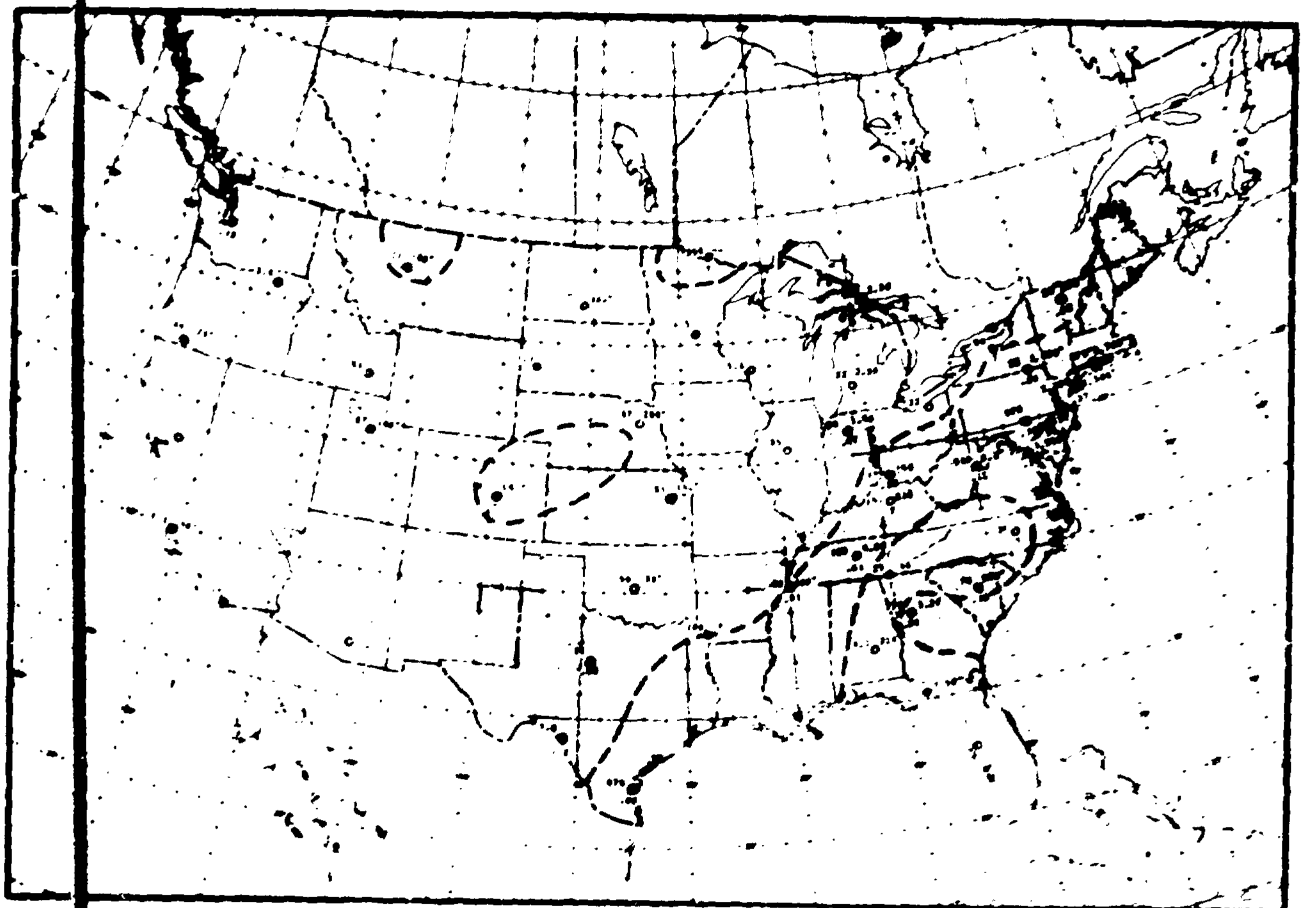


Fig. A.10 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 28 October 1951

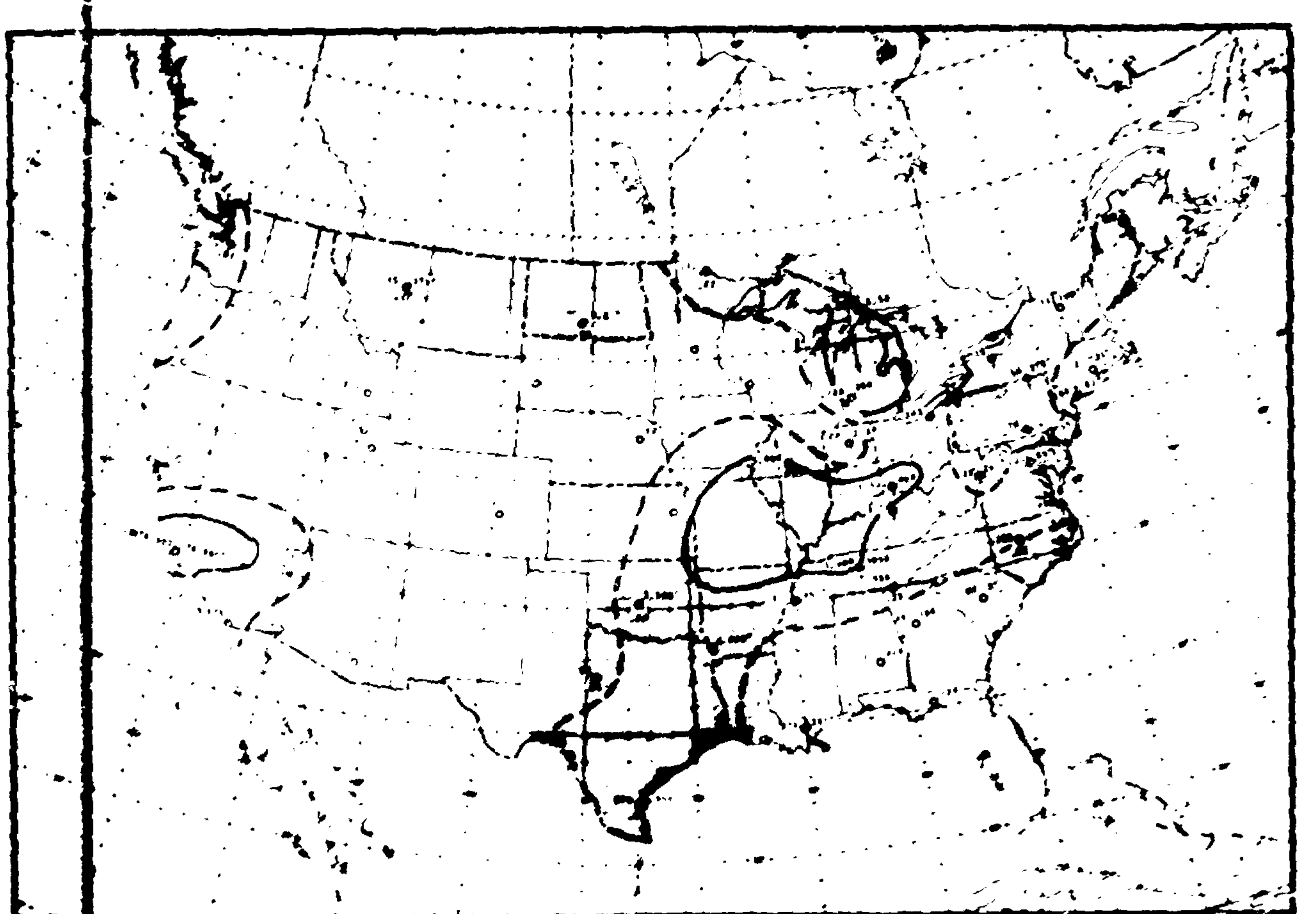


Fig. A.11 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 29 October 1953

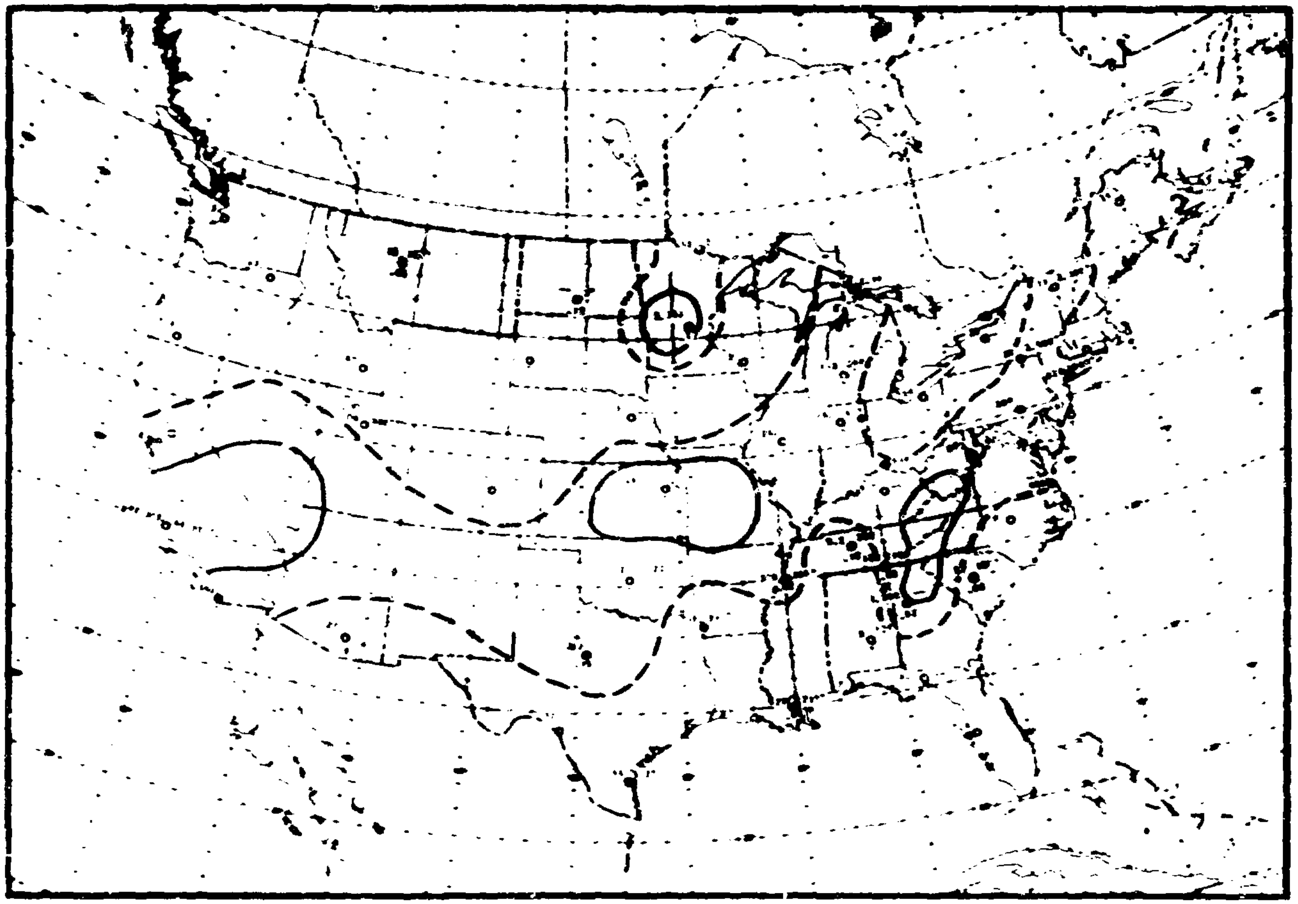


Fig. A.12 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 30 October 1951

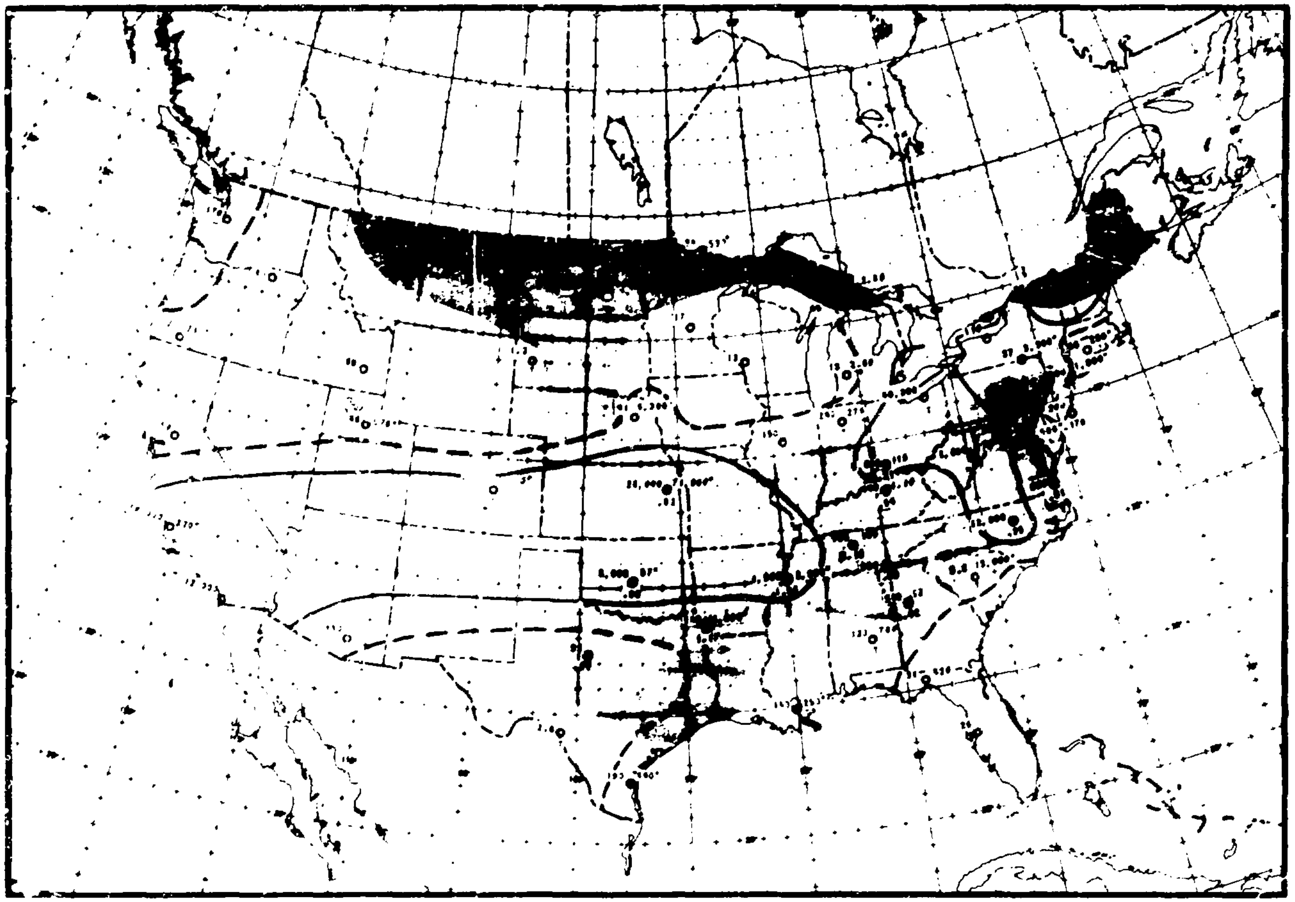


Fig. A.13 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 31 October 1951

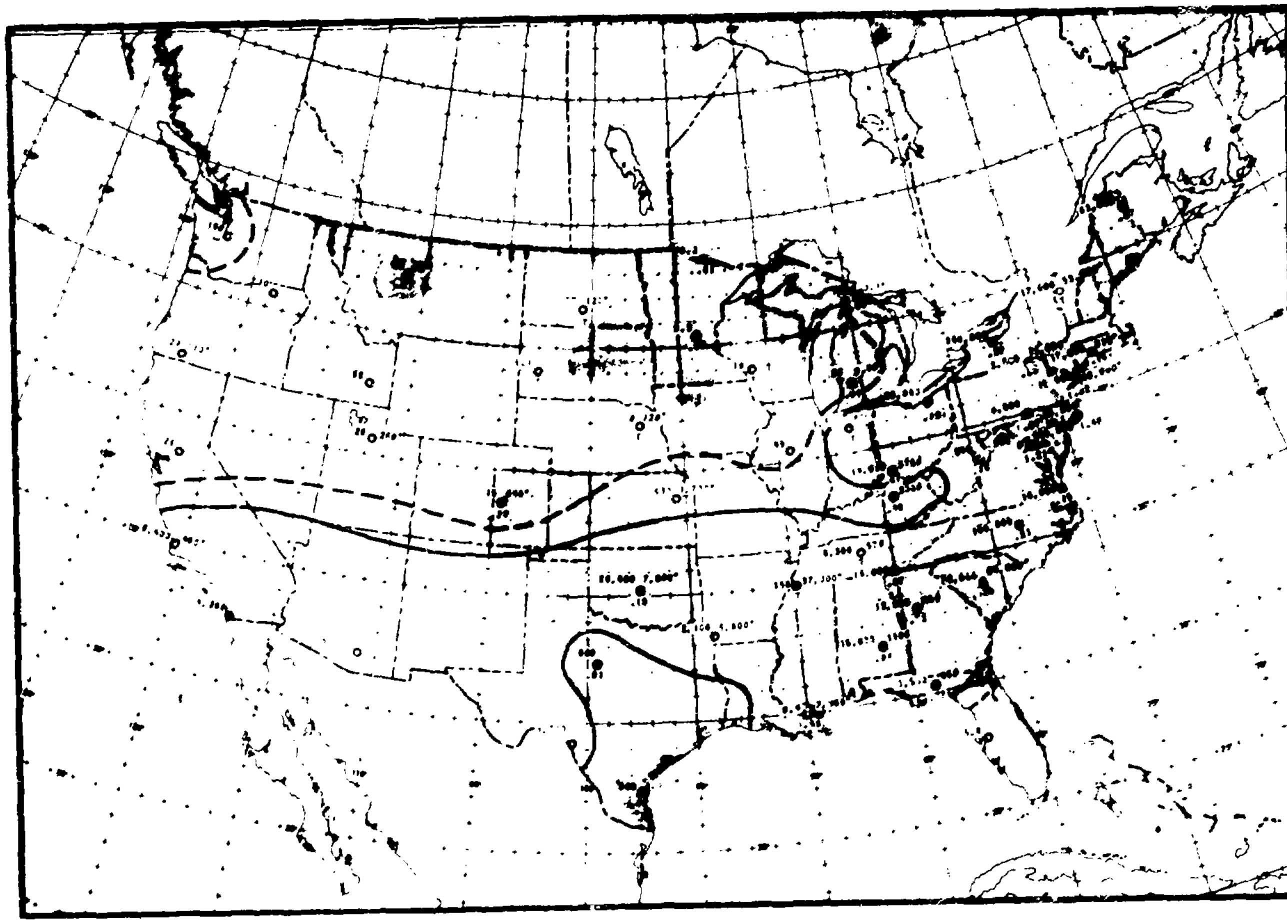


Fig. A.14 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 1 November 1951

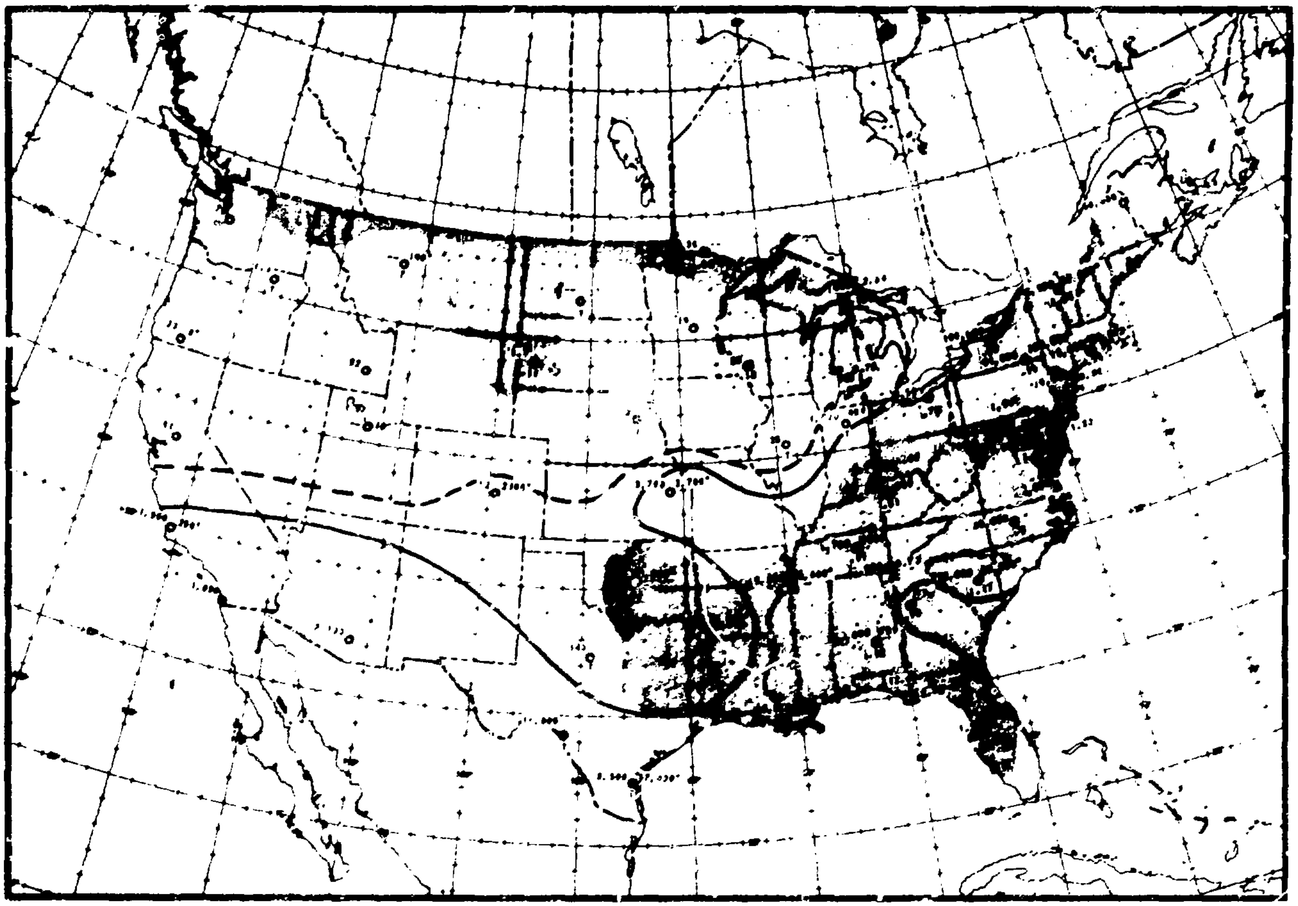


Fig. A.15 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 2 November 1951

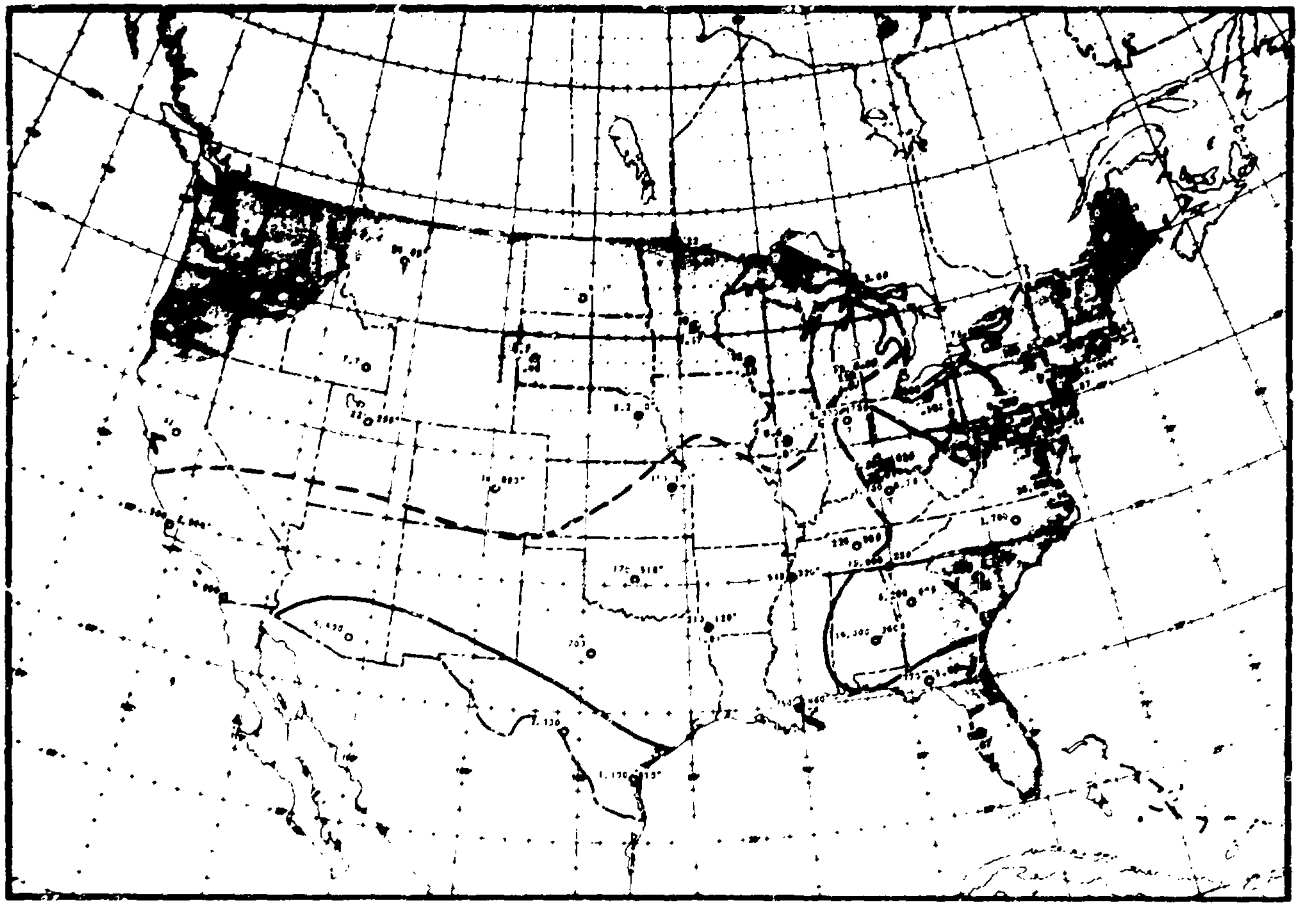


Fig. A.16 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 3 November 1951

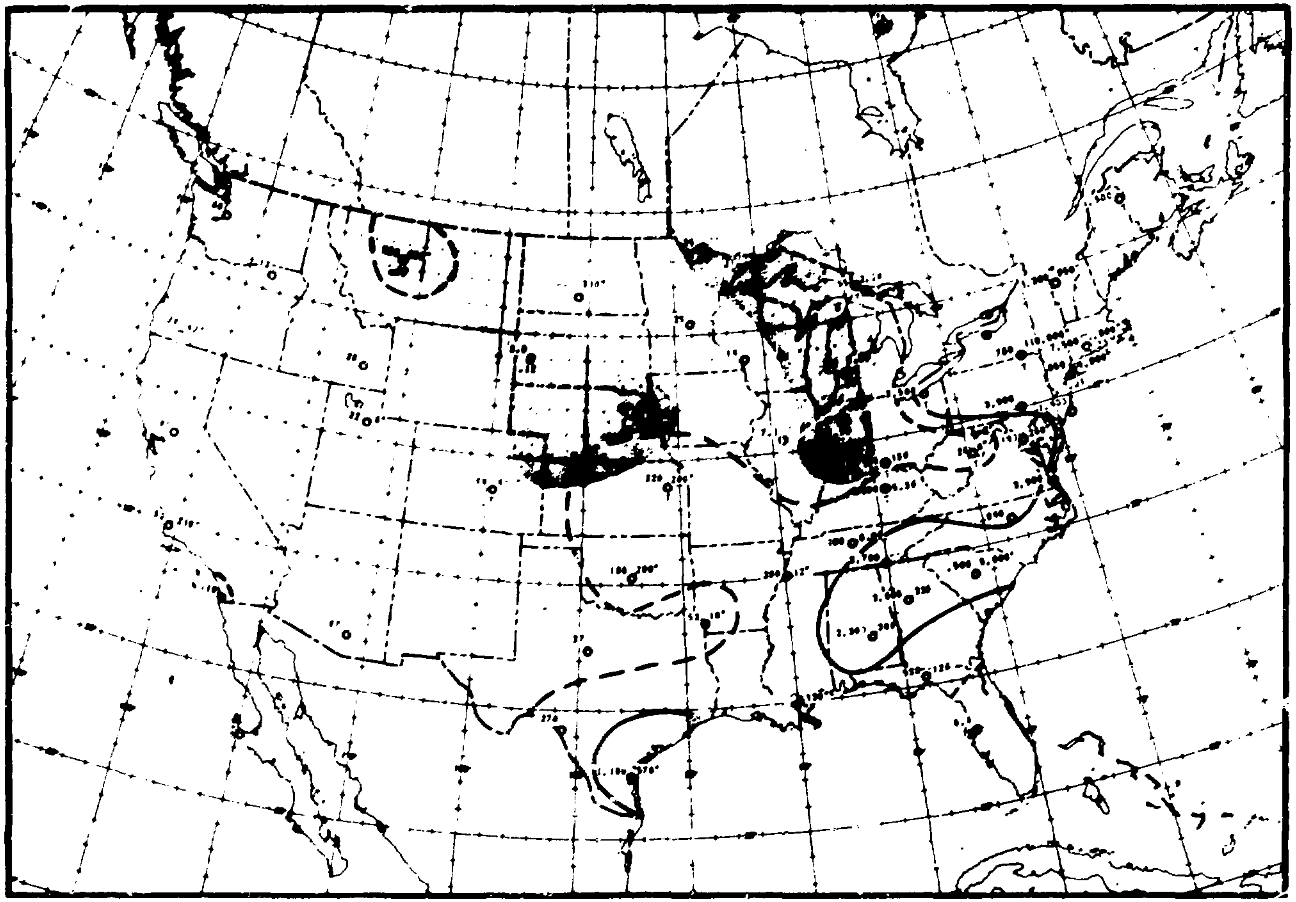


Fig. A.17 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 4 November 1951

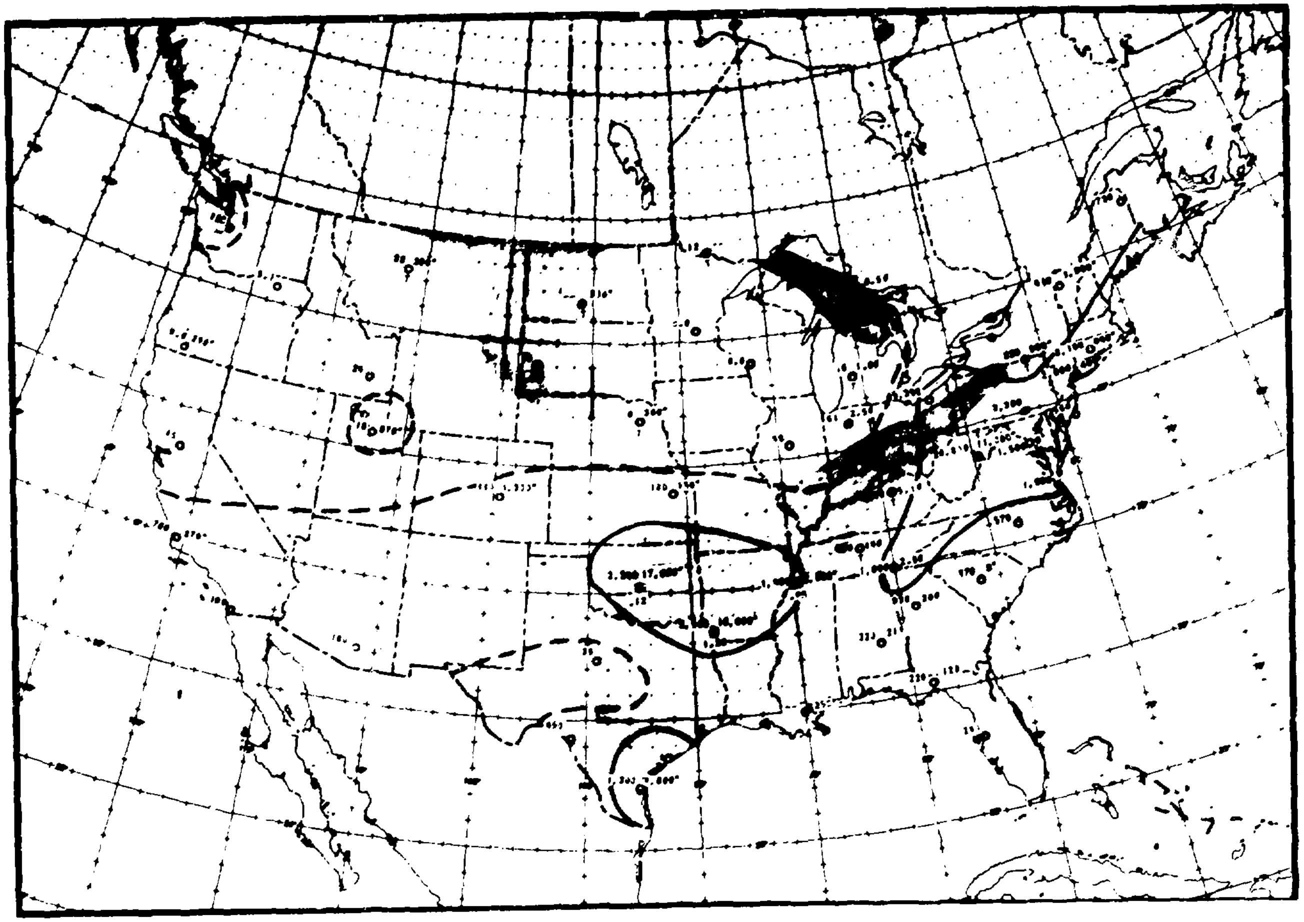


Fig. A.18 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 5 November 1951

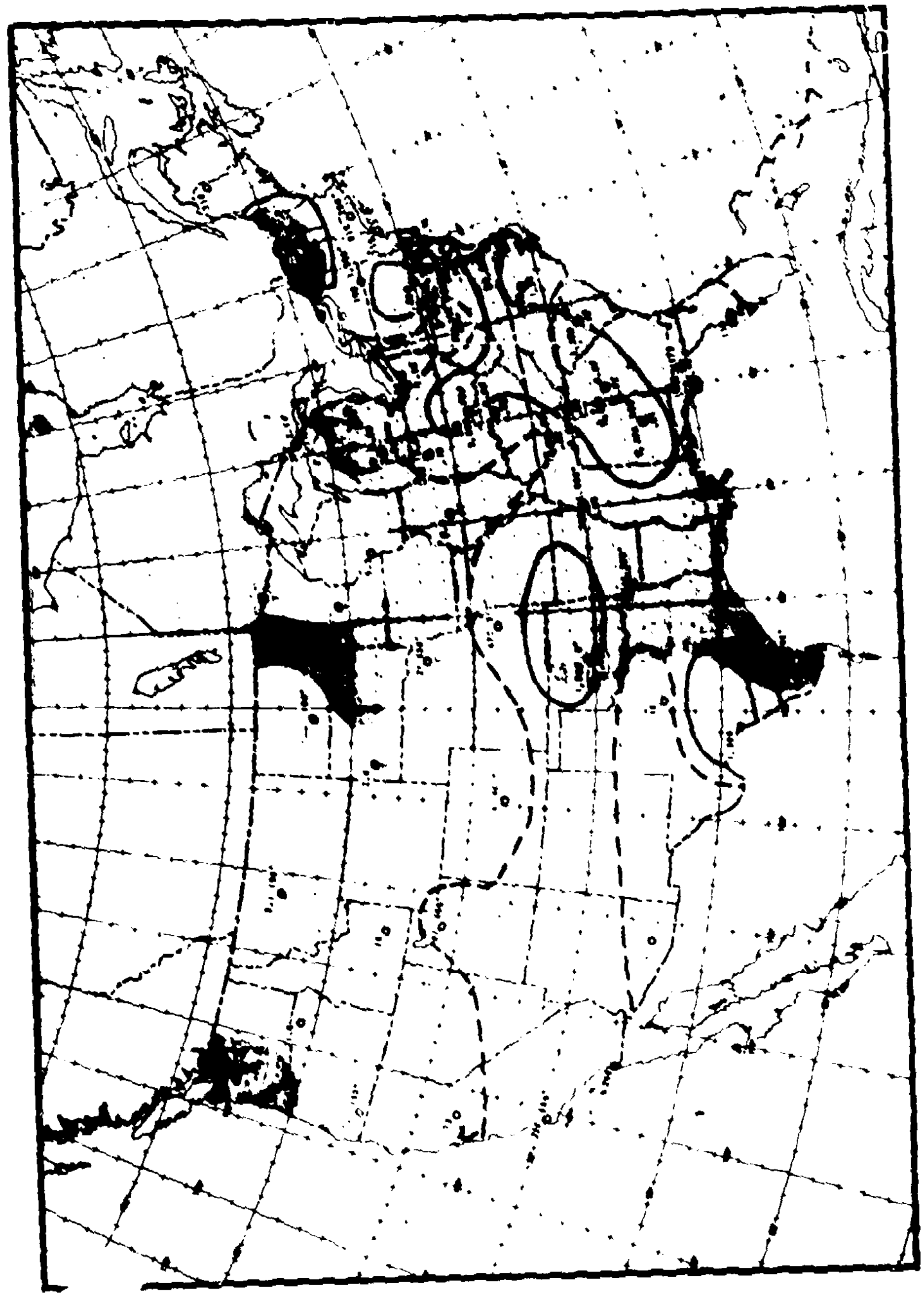


Fig. A.19 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 6 November 1951

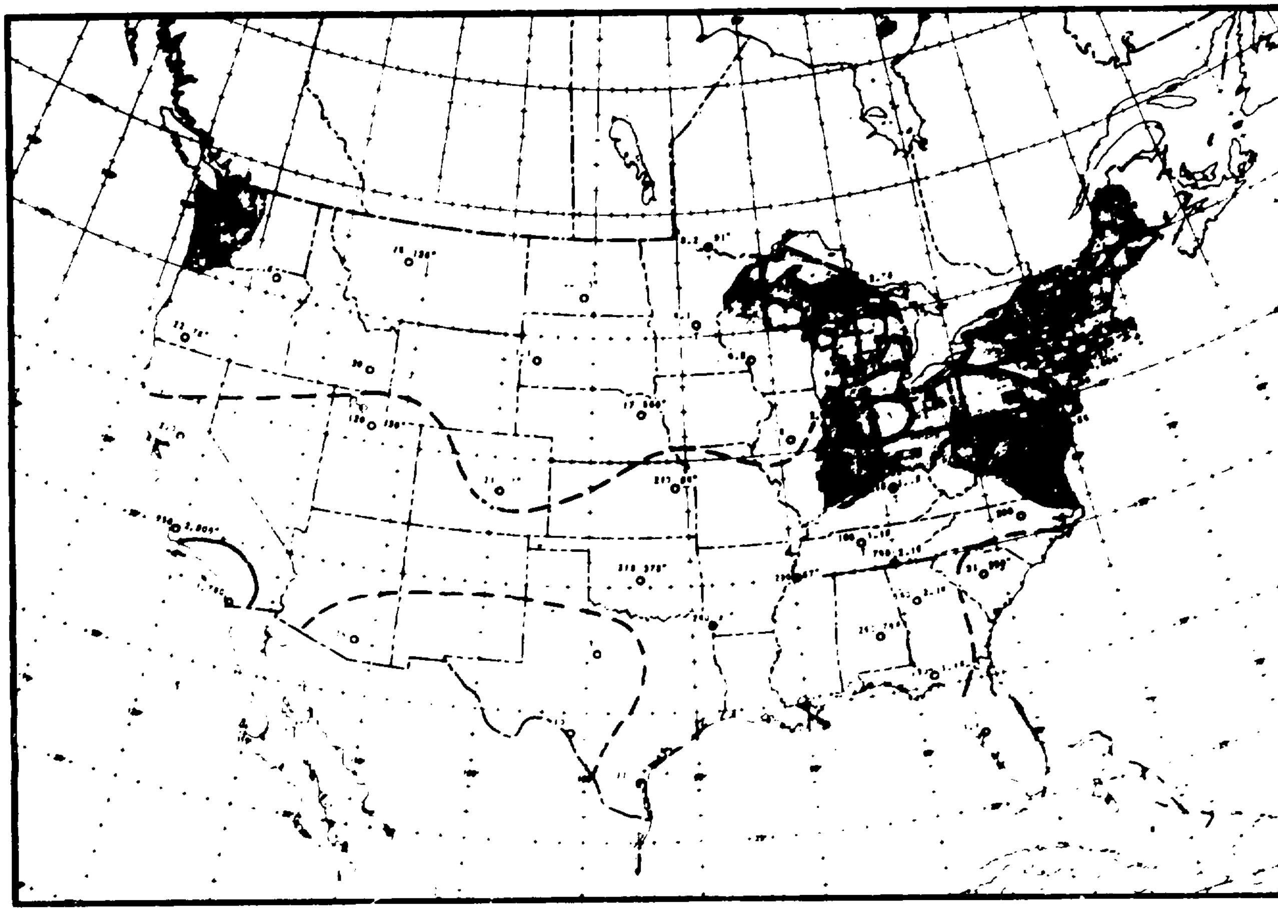


Fig. A.20 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 7 November 1951

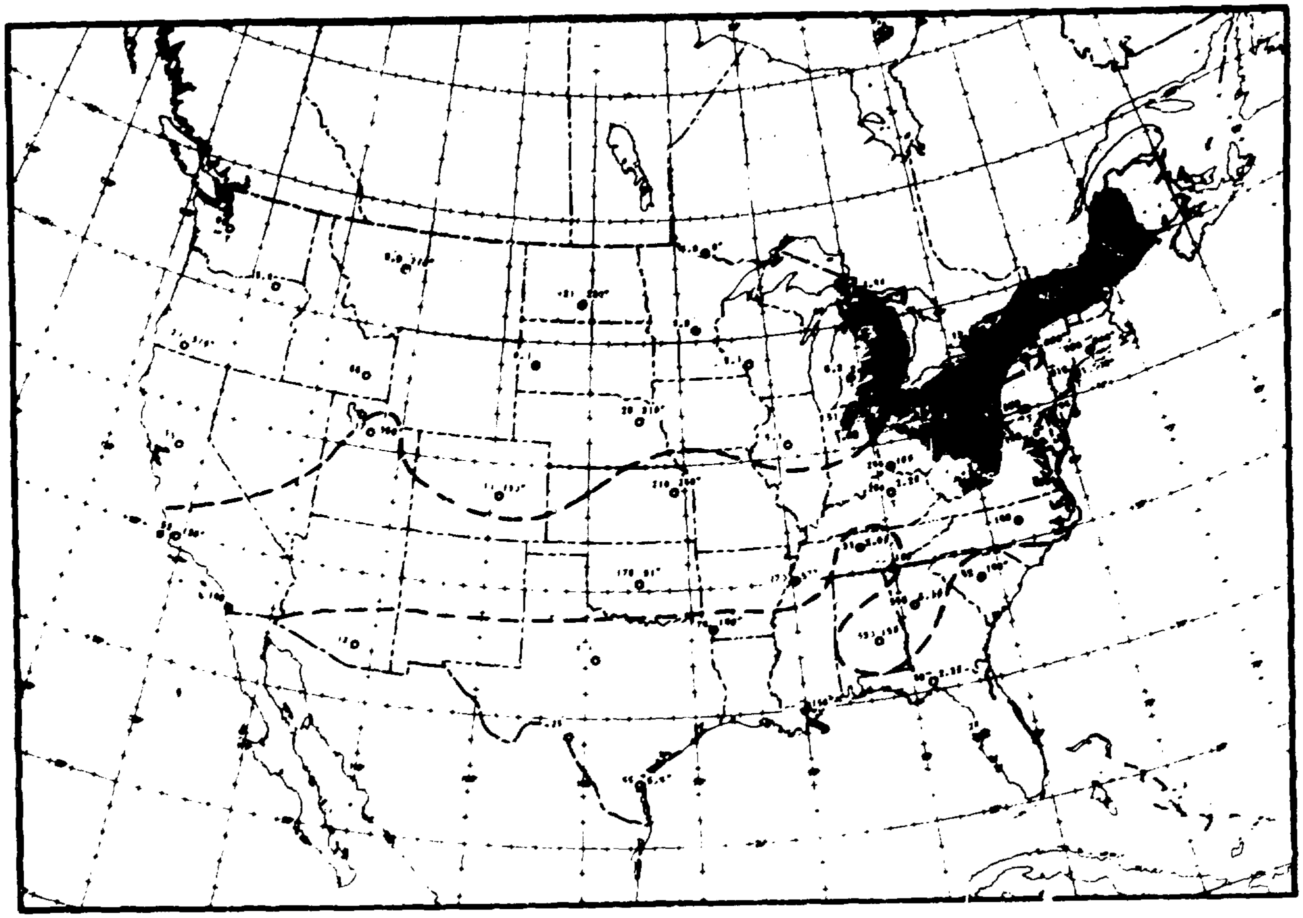


Fig. A.21 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 8 November 1951

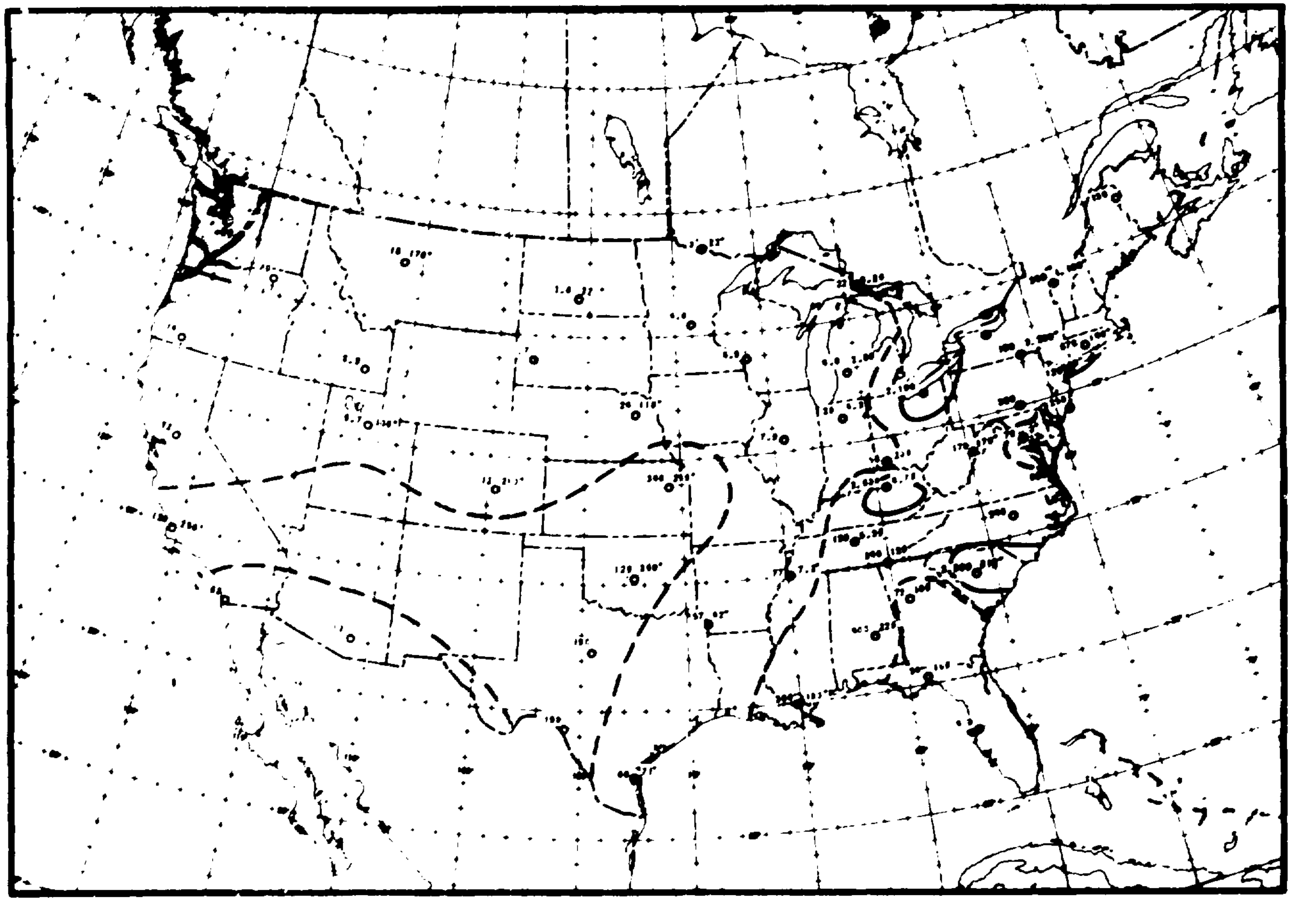


Fig. A.22 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 9 November 1951

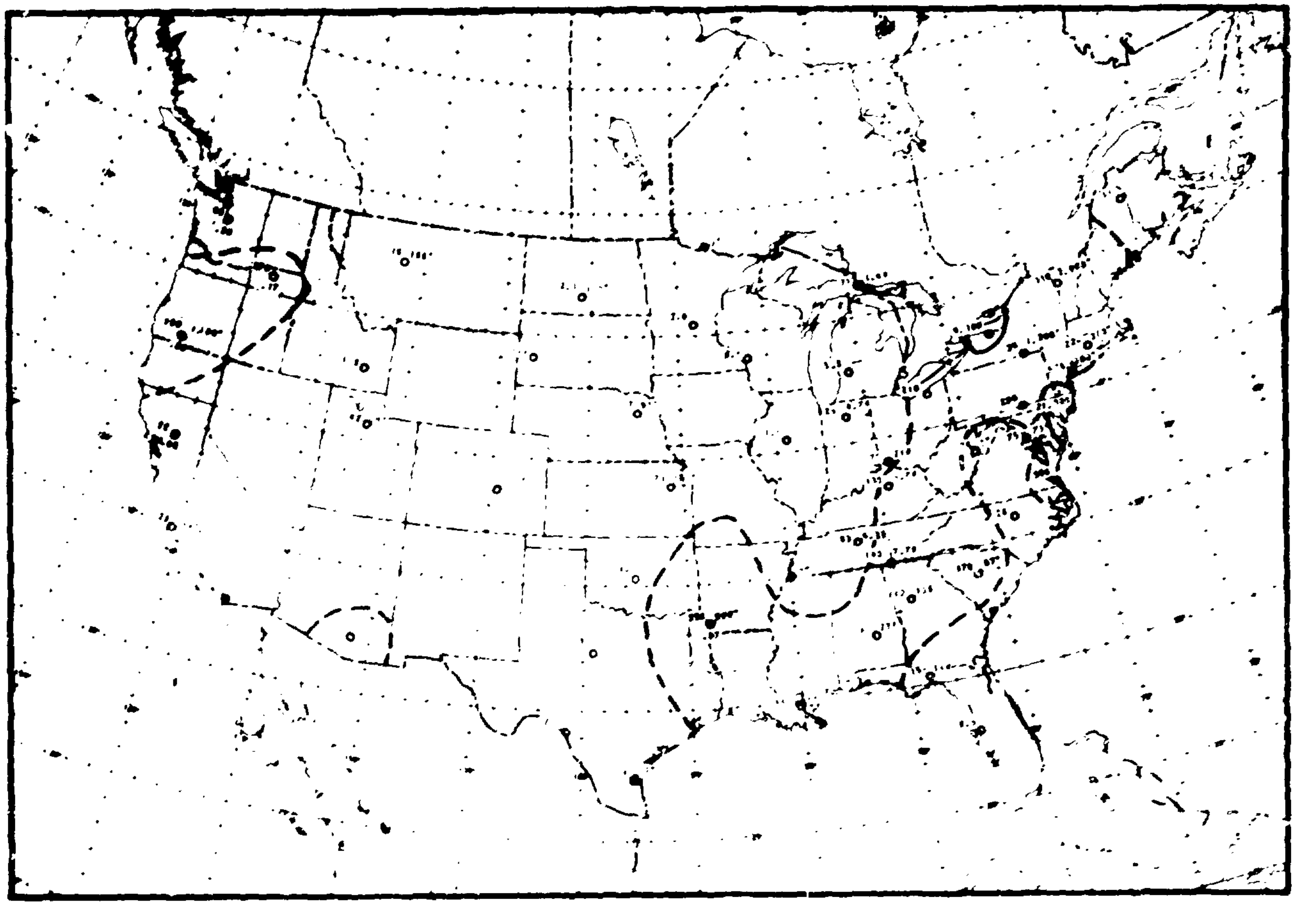


Fig. A.23 Surface Distribution of Radioactive Debris
and Concurrent Precipitation, 10 November 1951

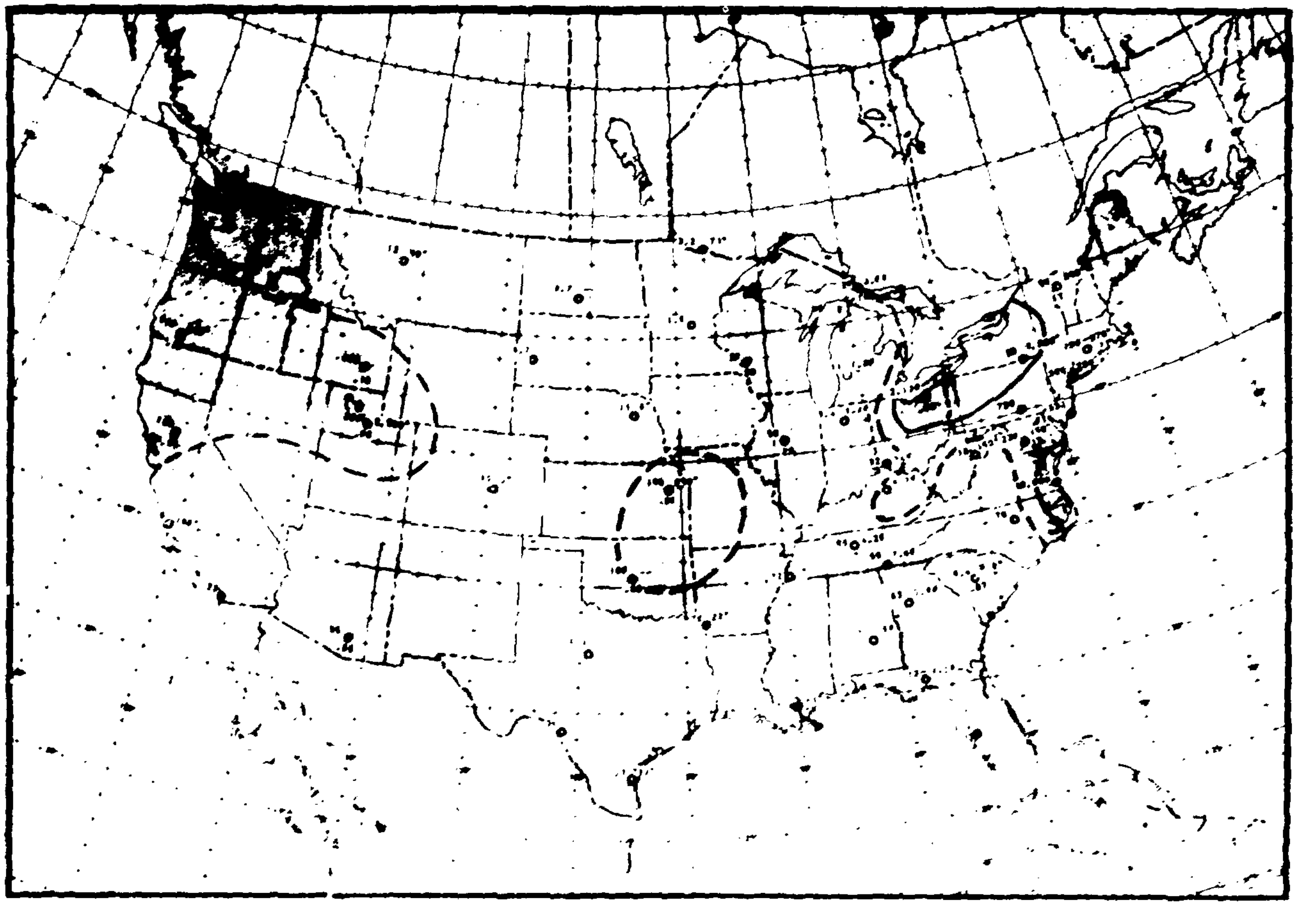


Fig. A.24 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 11 November 1951

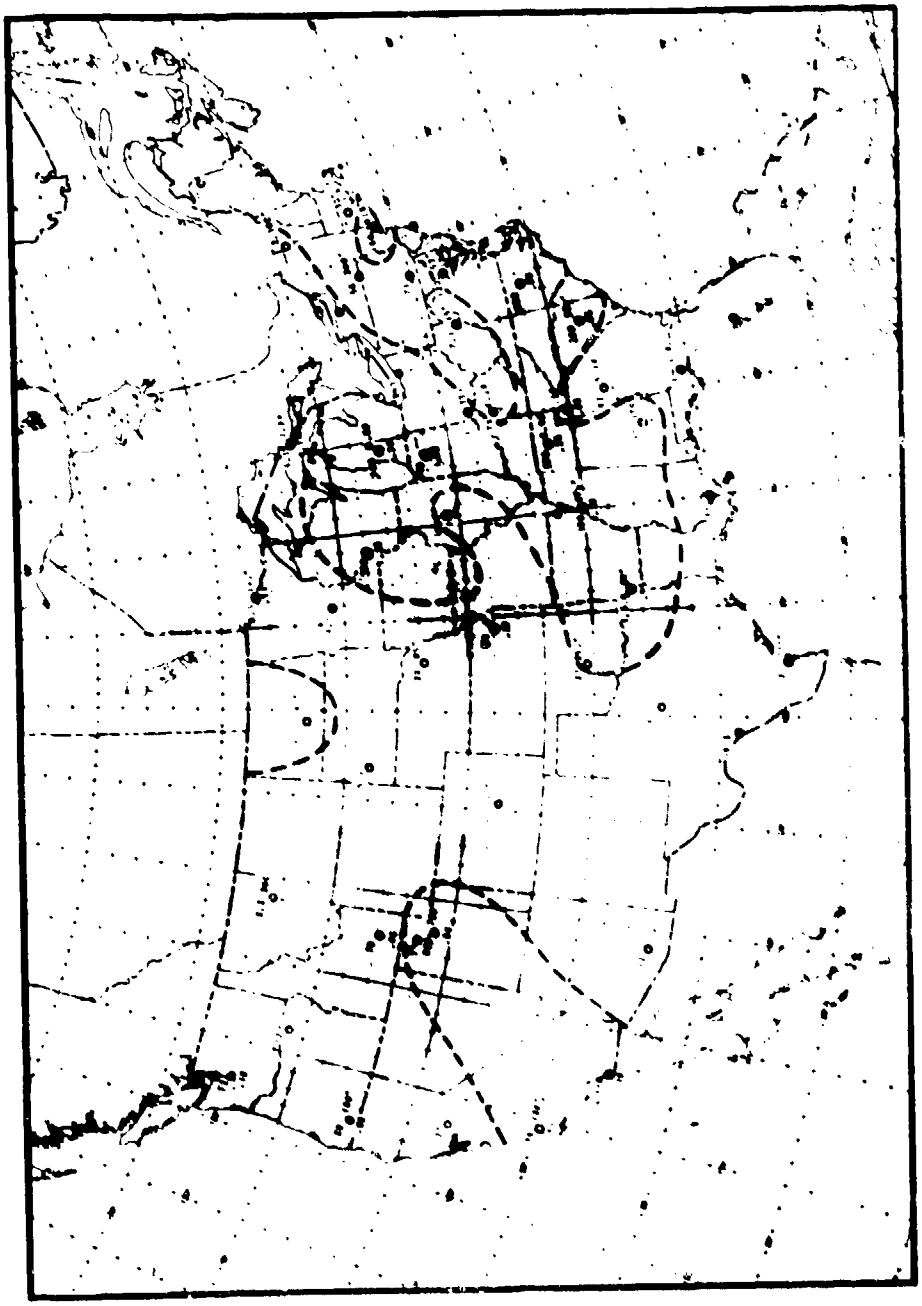


Fig. A.25 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 12 November 1951

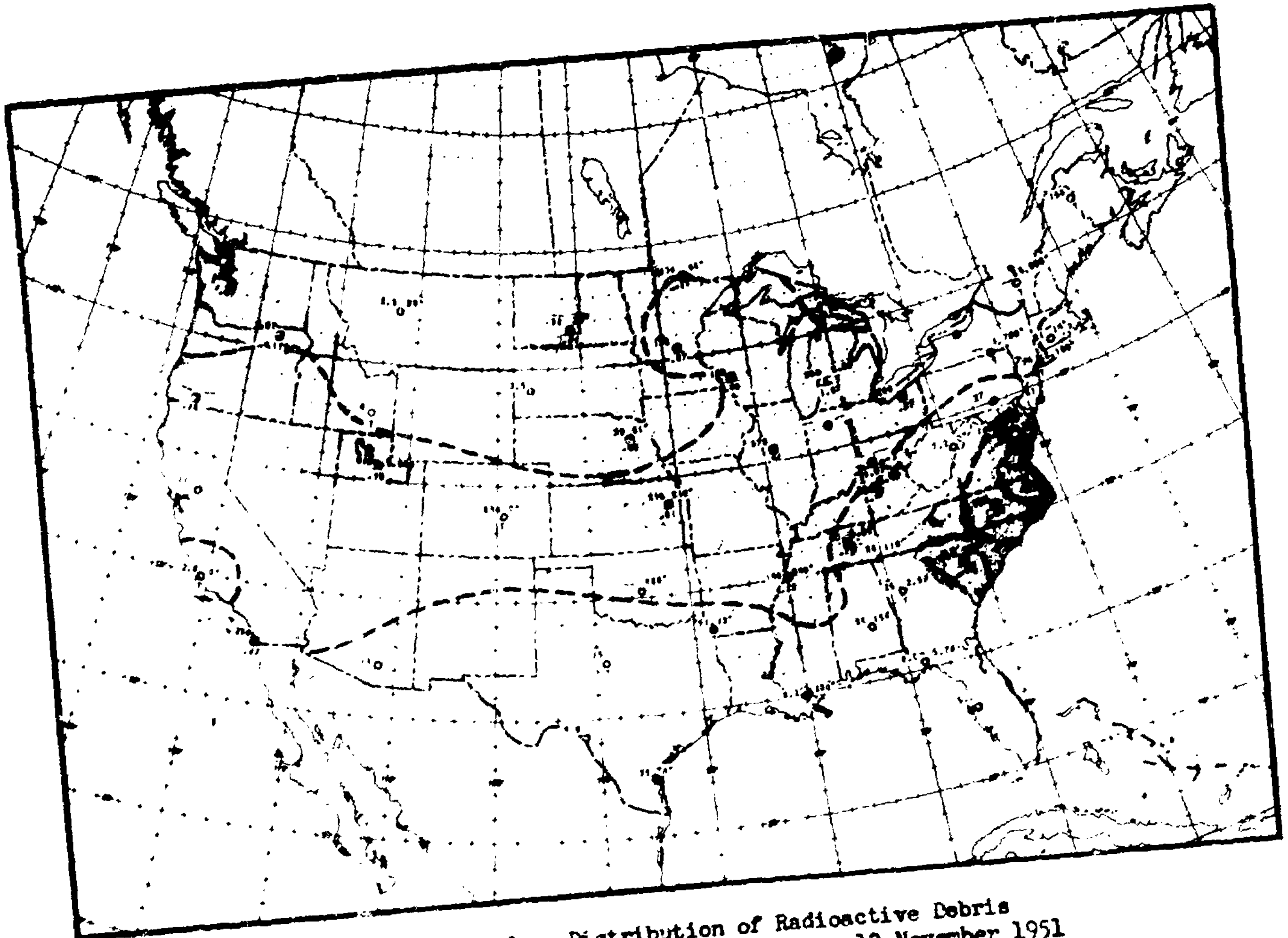


Fig. 4.26 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 13 November 1951

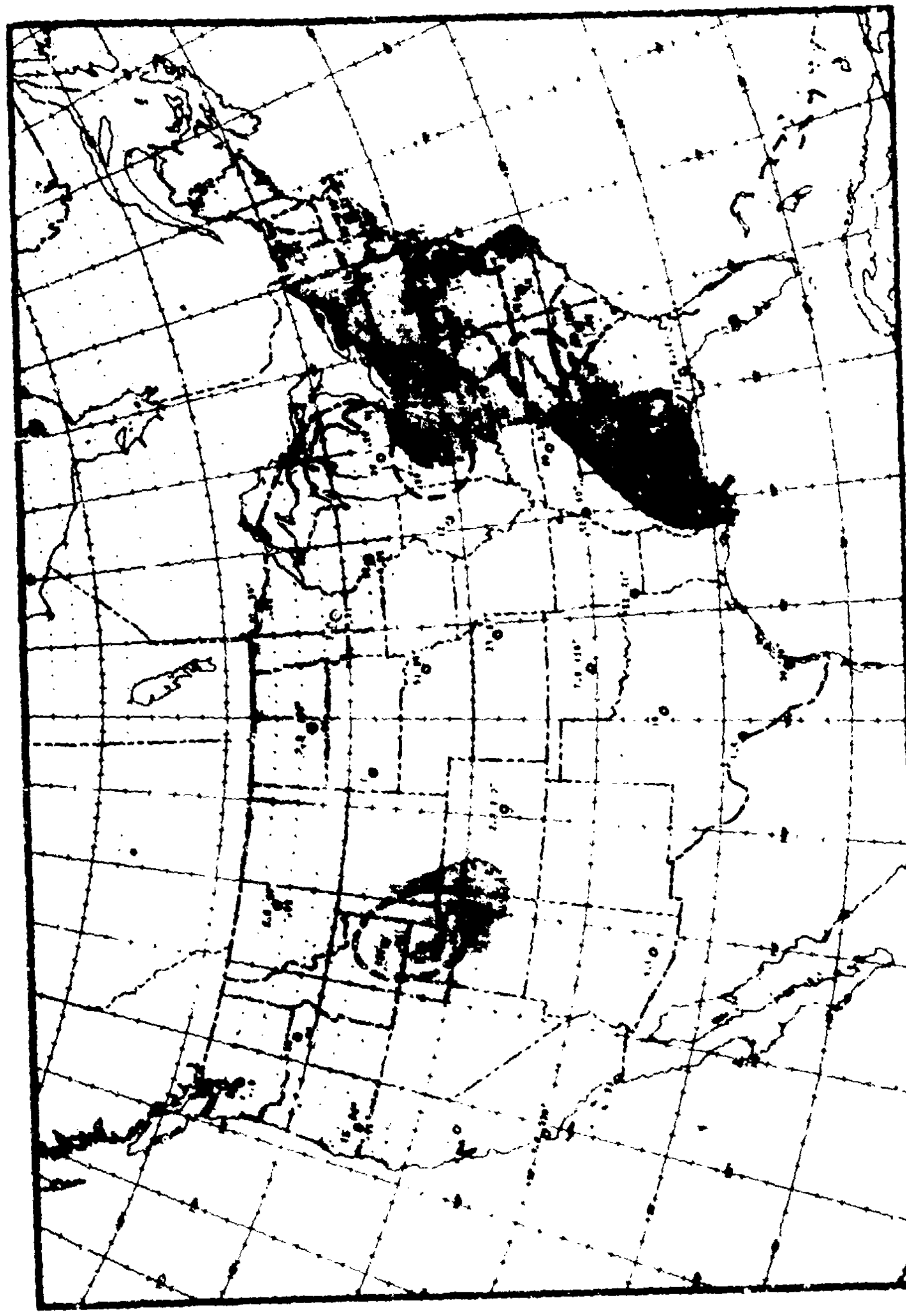


Fig. A.27 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 14 November 1951

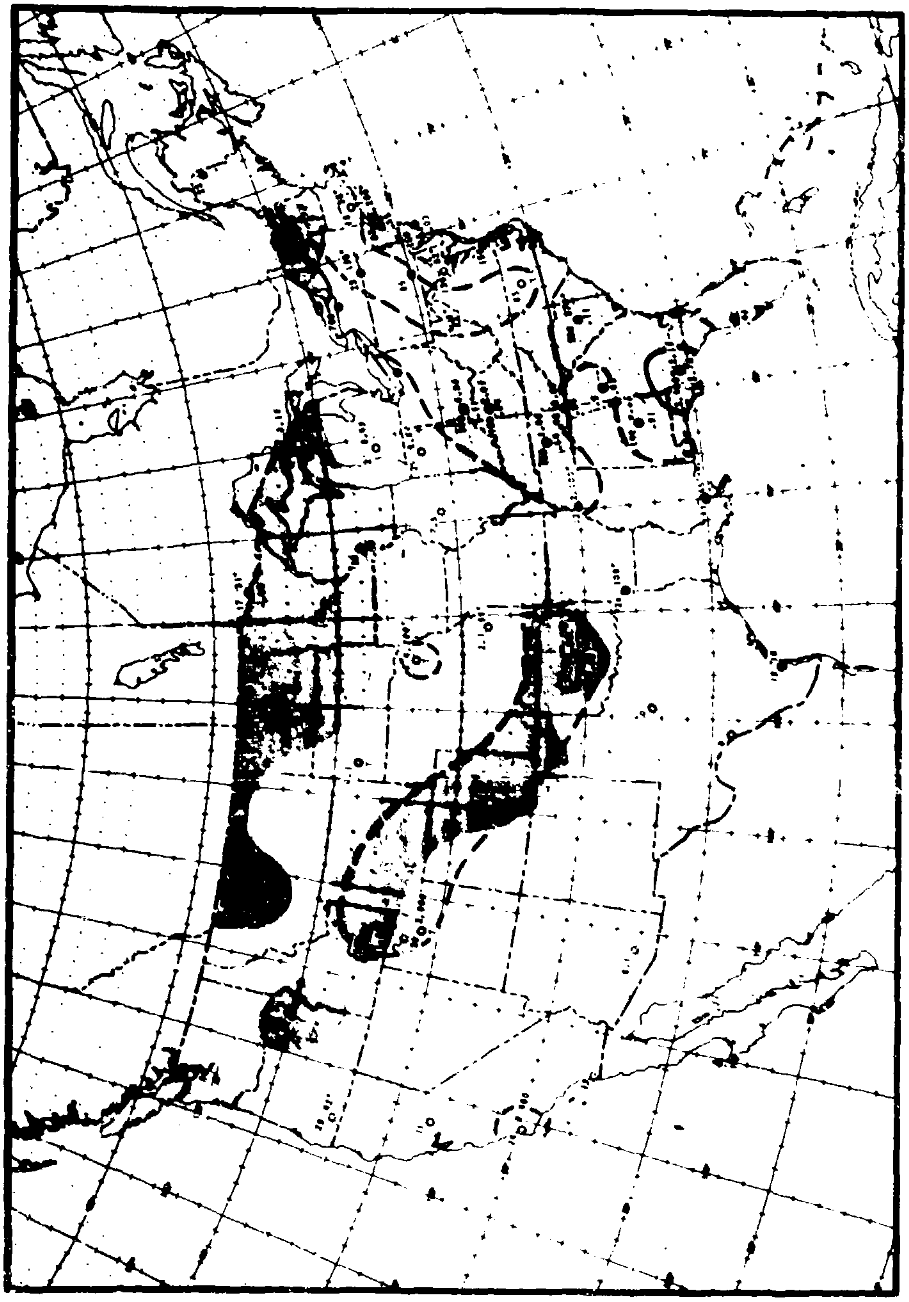


Fig. A.28 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 15 November 1951

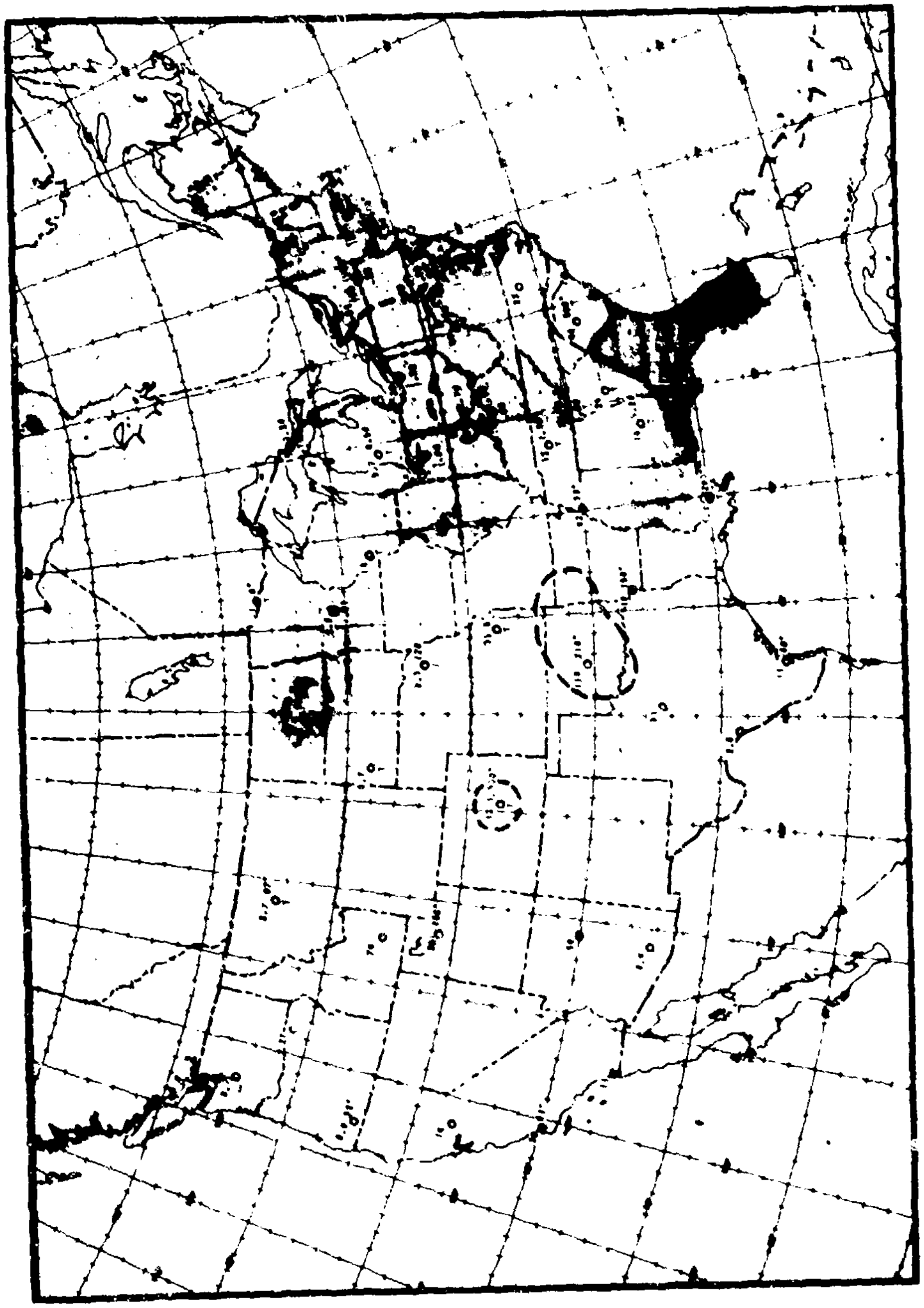


Fig. A.29 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 16 November 1951

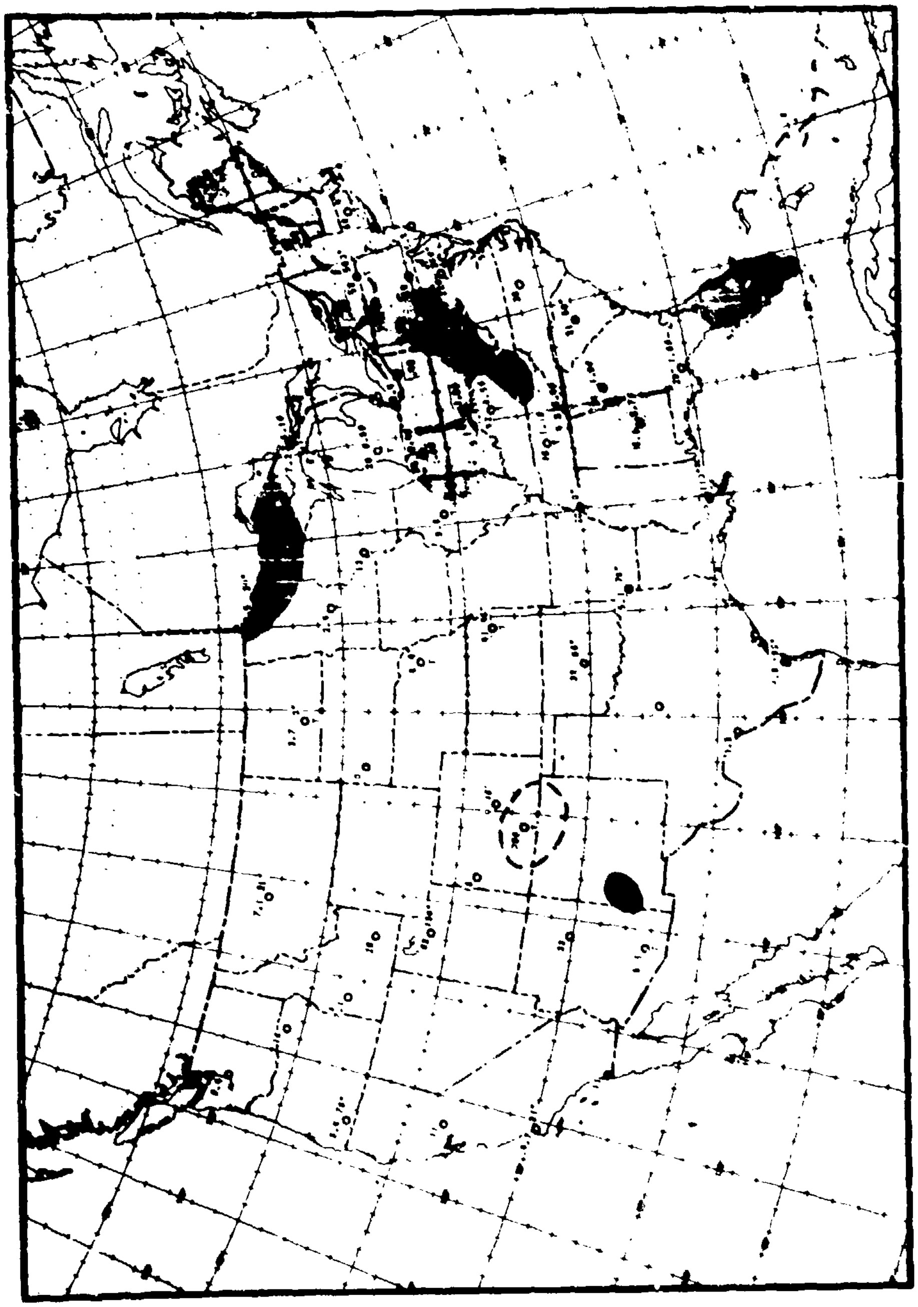


Fig. A.30 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 17 November 1951

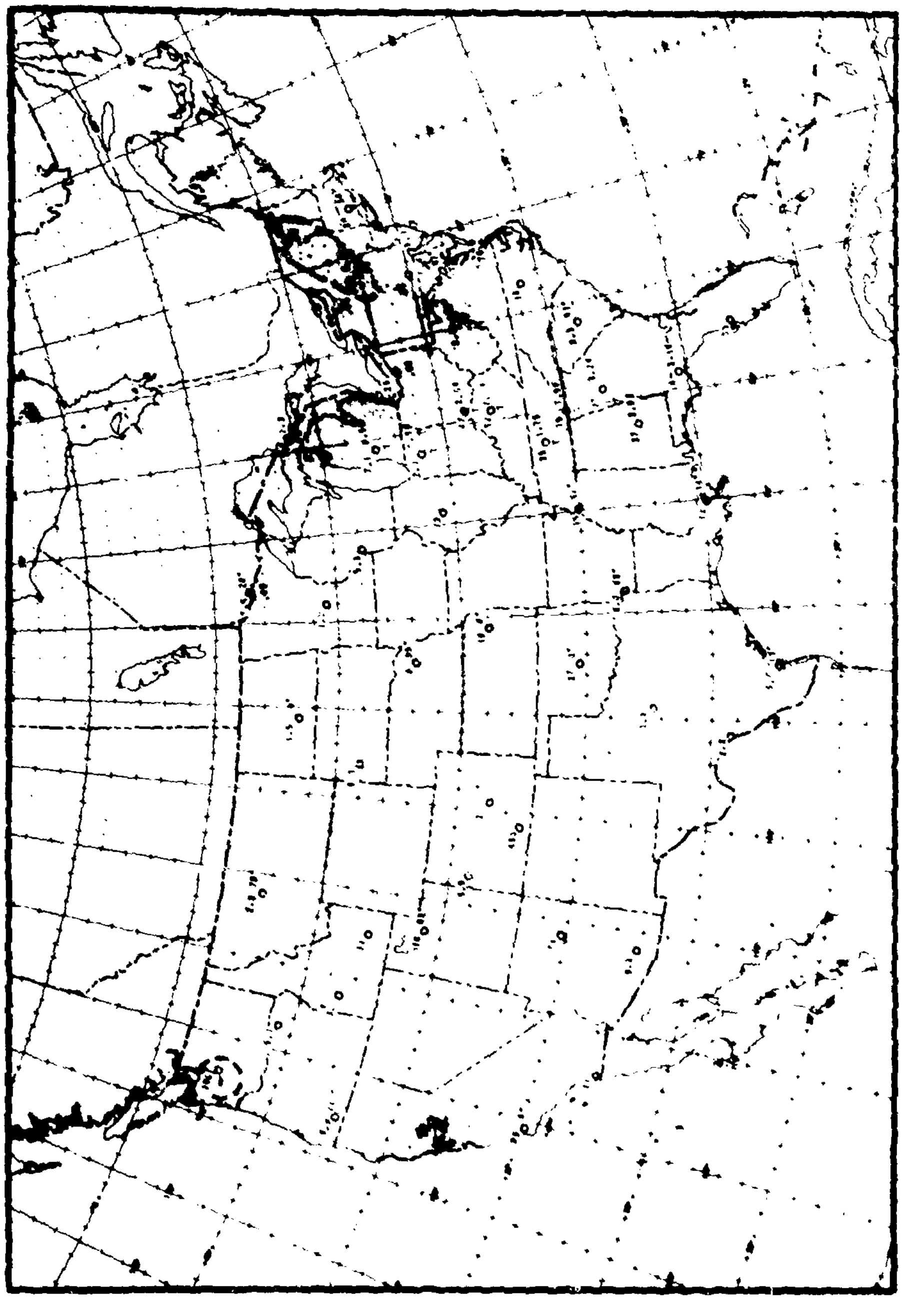


Fig. A.31 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 18 November 1951

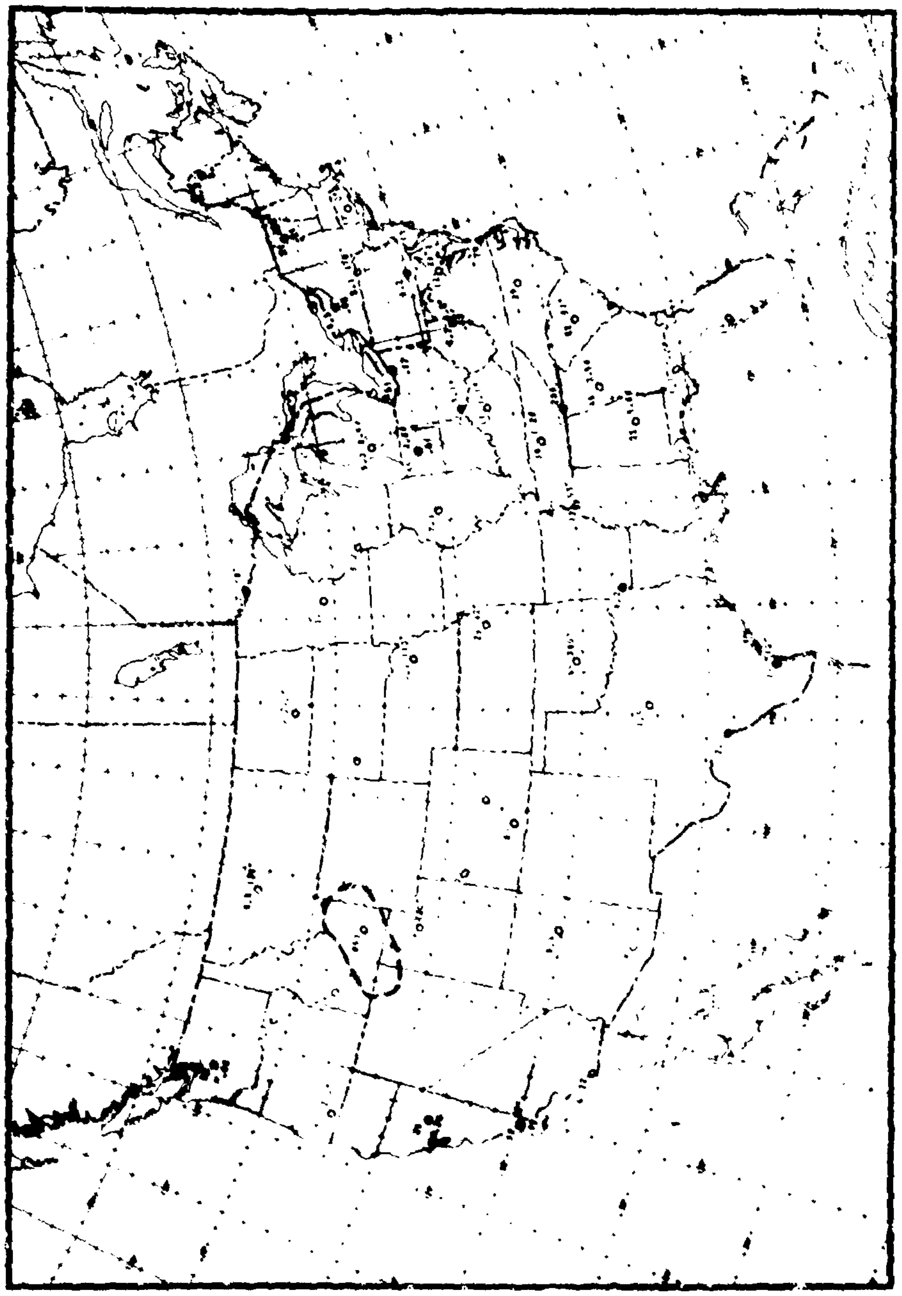


Fig. A.32 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 19 November 1951

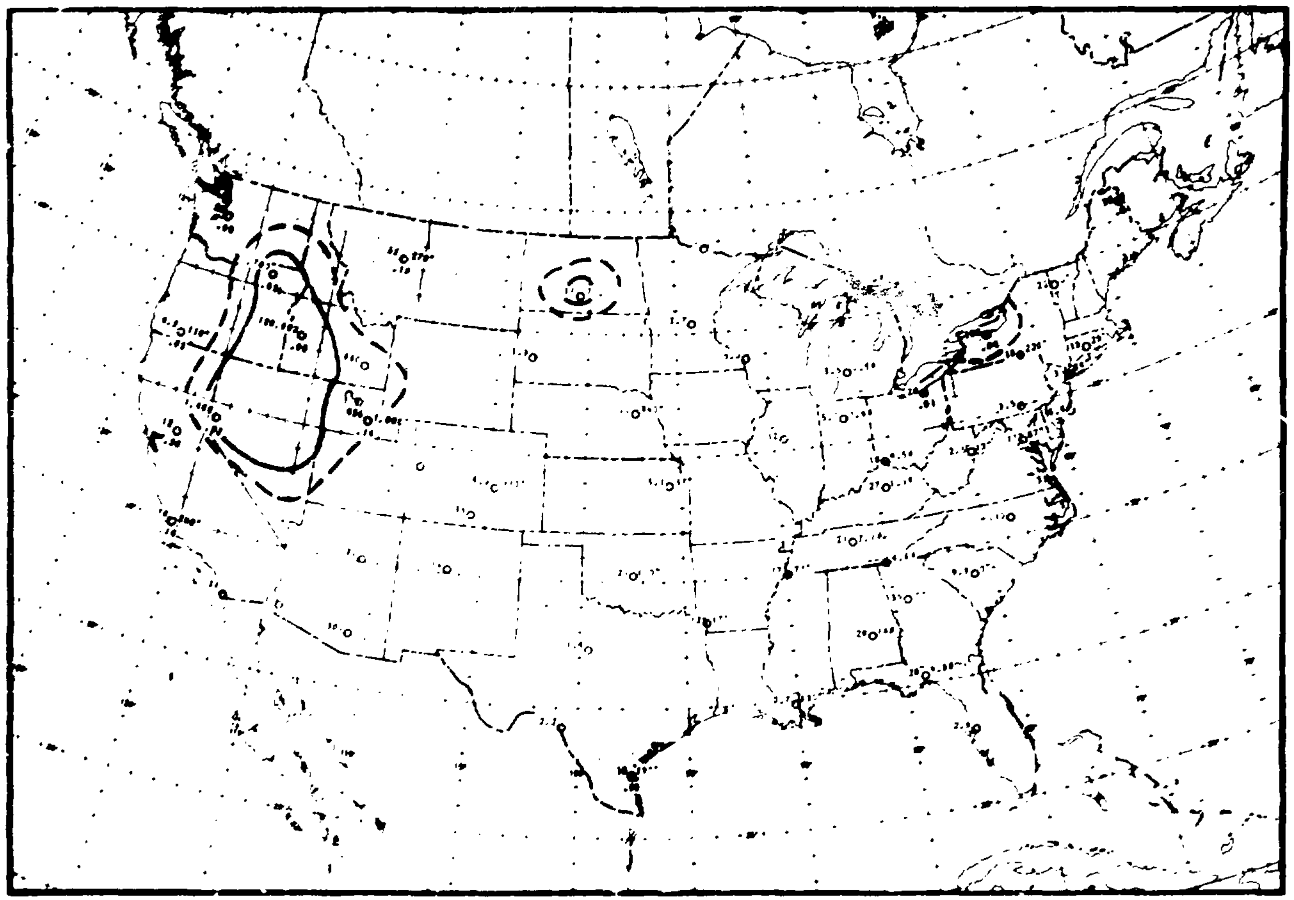


Fig. A.33 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 20 November 1951

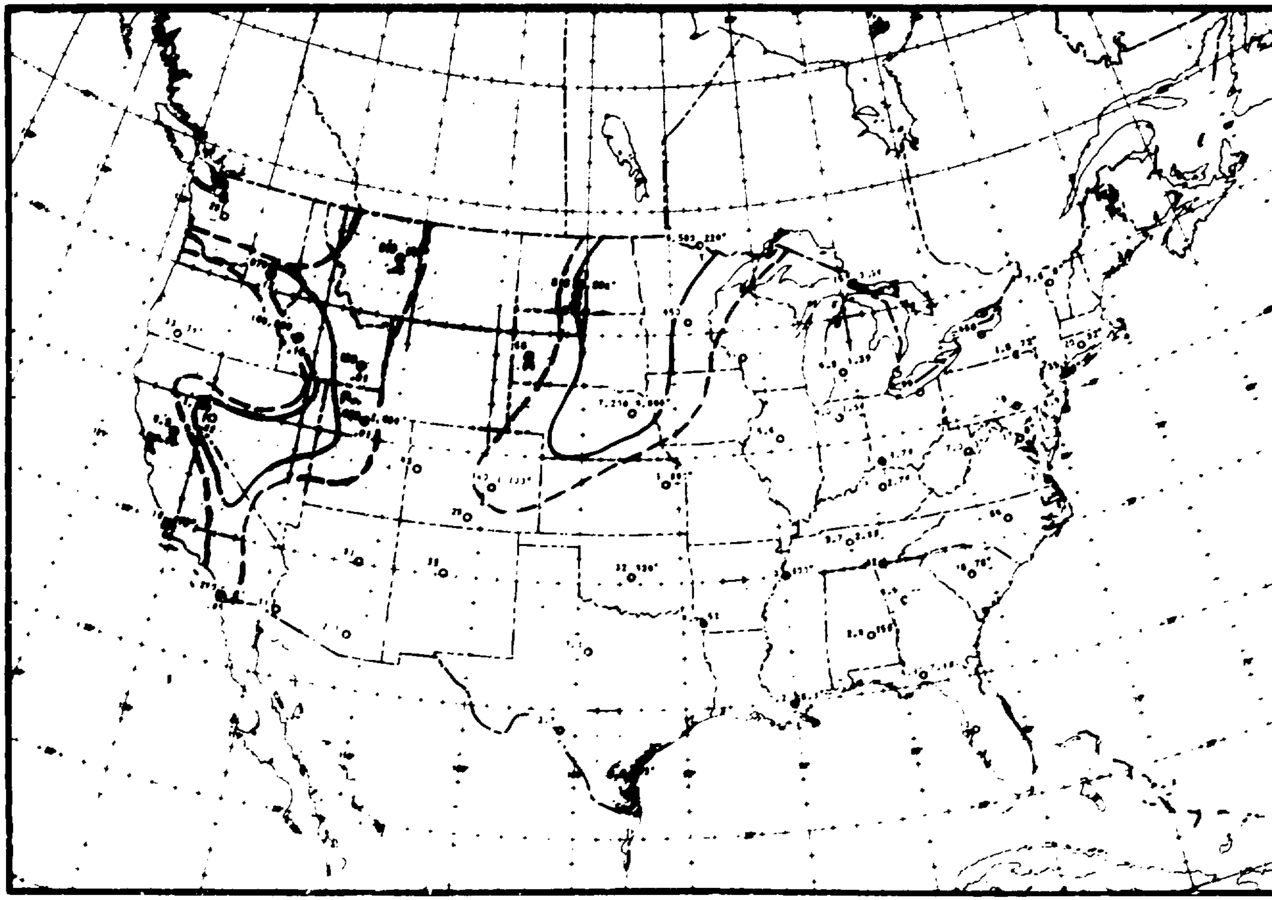


Fig. A.34 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 21 November 1951

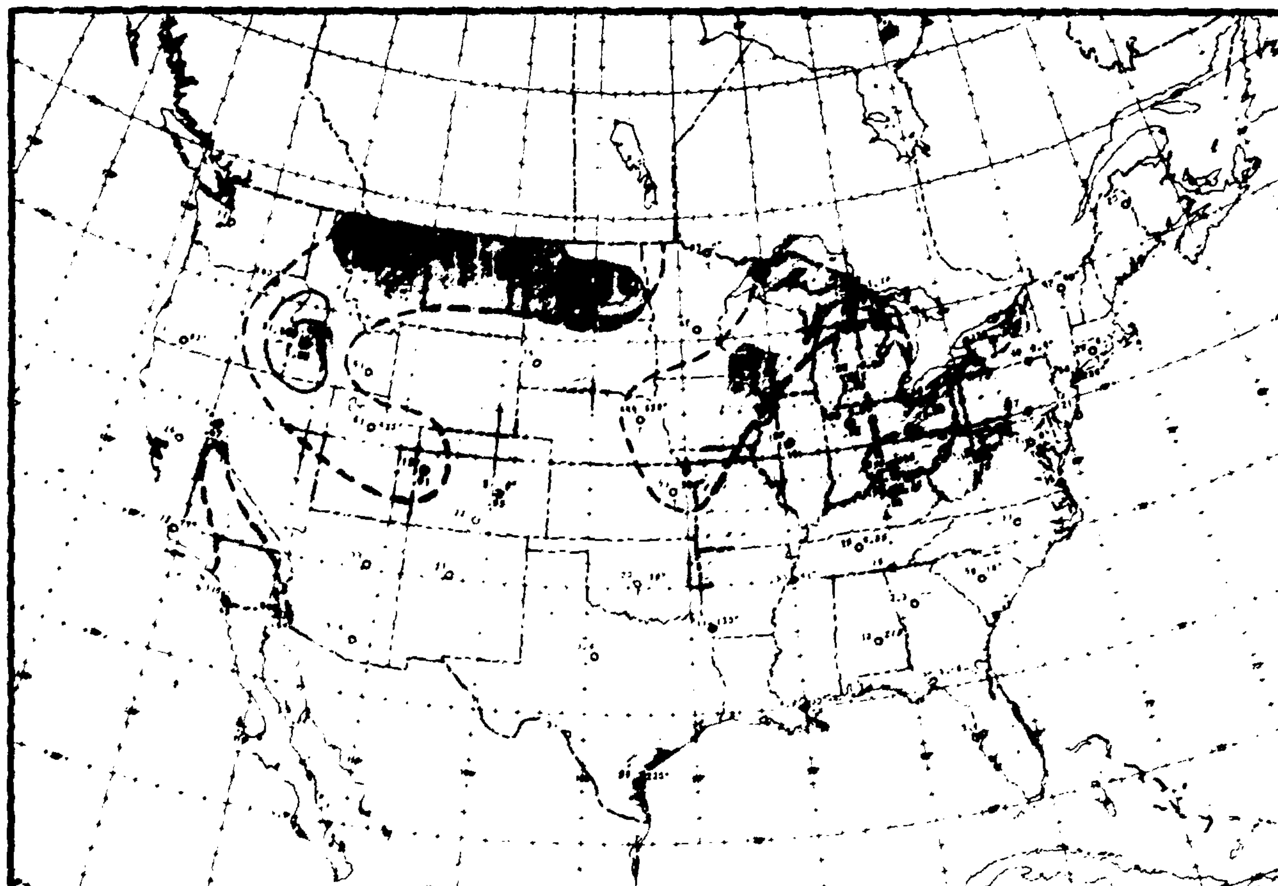


Fig. A.35 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 22 November 1951

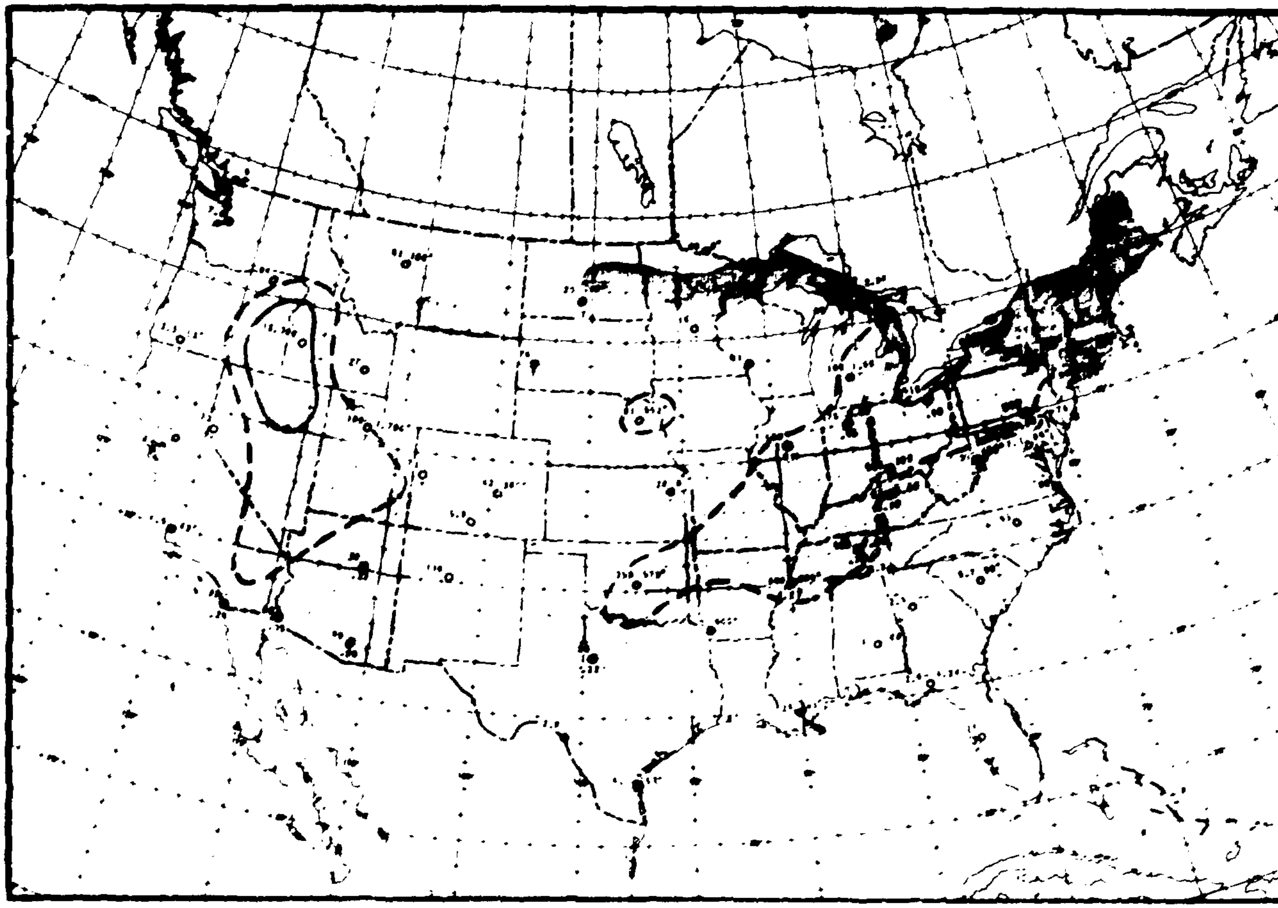


Fig. A.36 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 23 November 1951

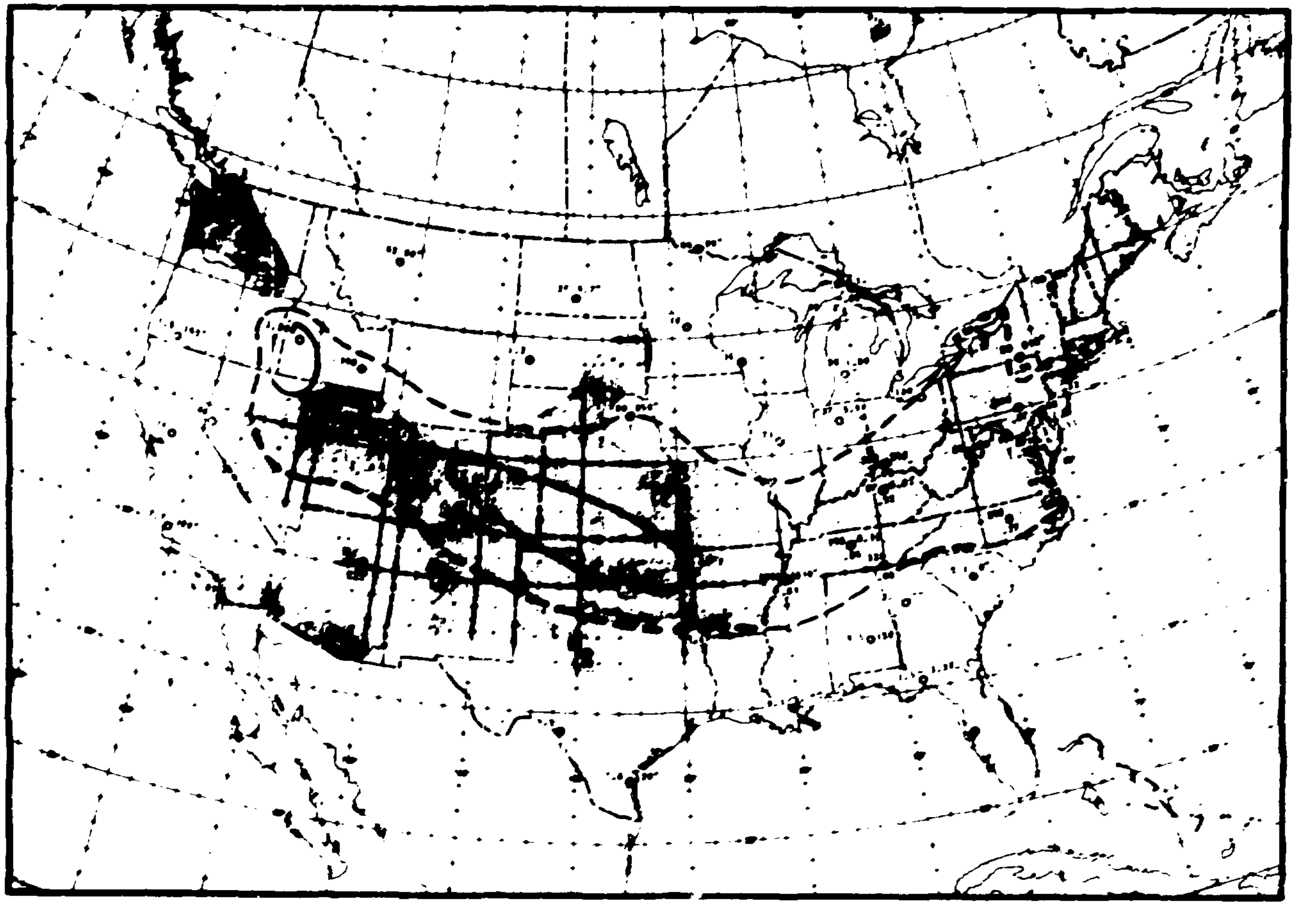


Fig. A.37 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 24 November 1951

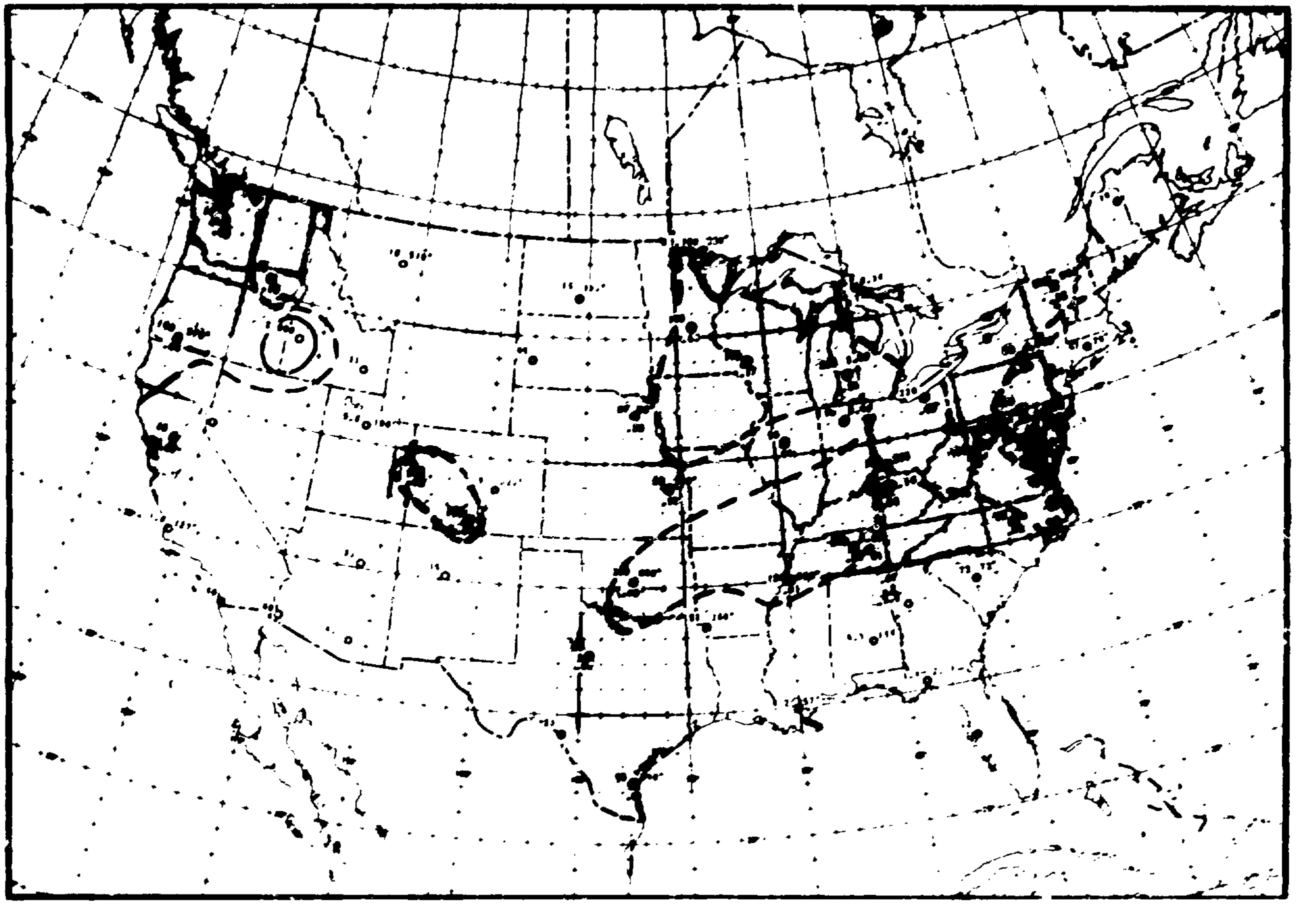


Fig. A.38 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 25 November 1951

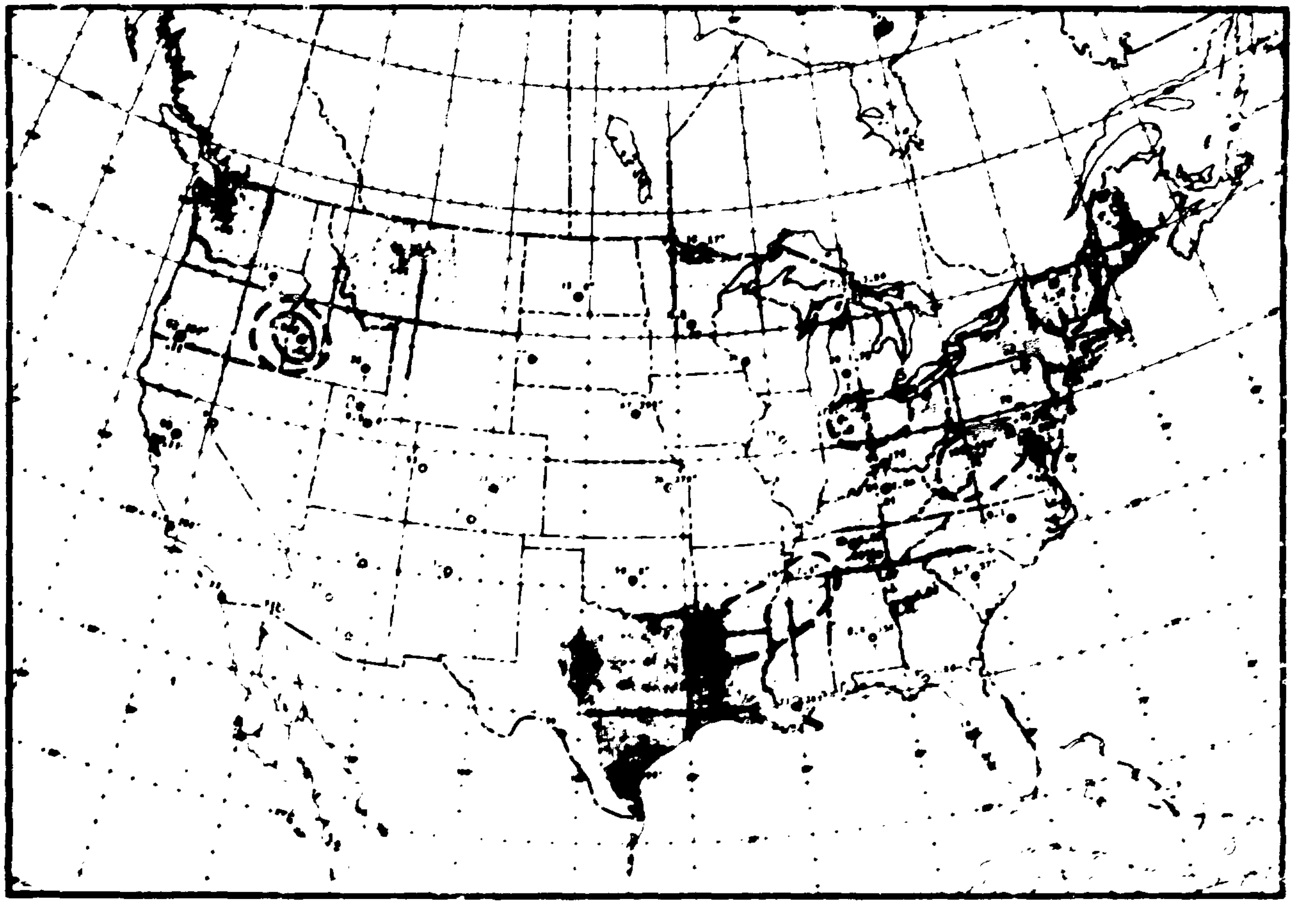


Fig. A.39 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 26 November 1951

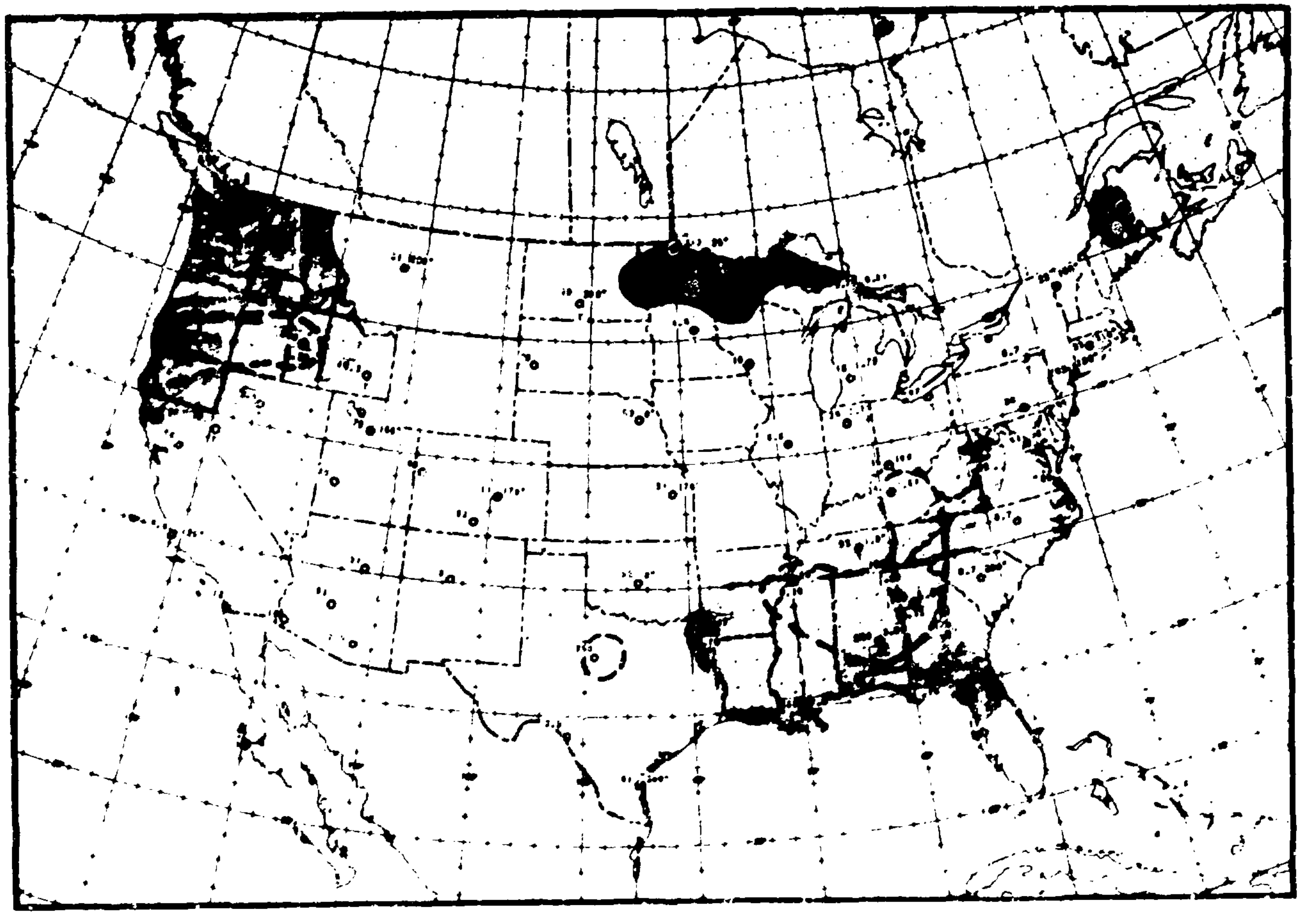


Fig. A.40 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 27 November 1951

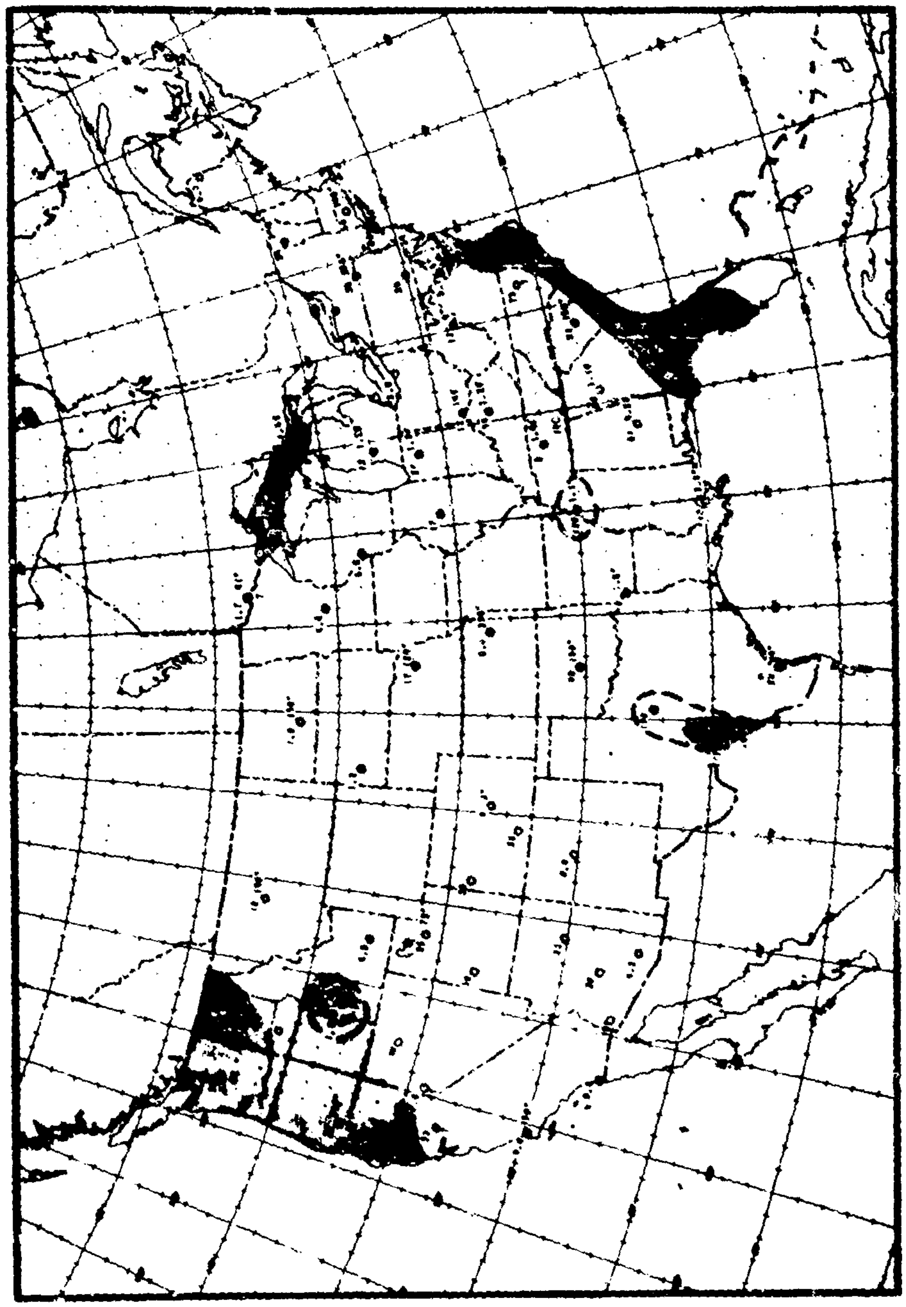


Fig. 4.41 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 28 November 1951

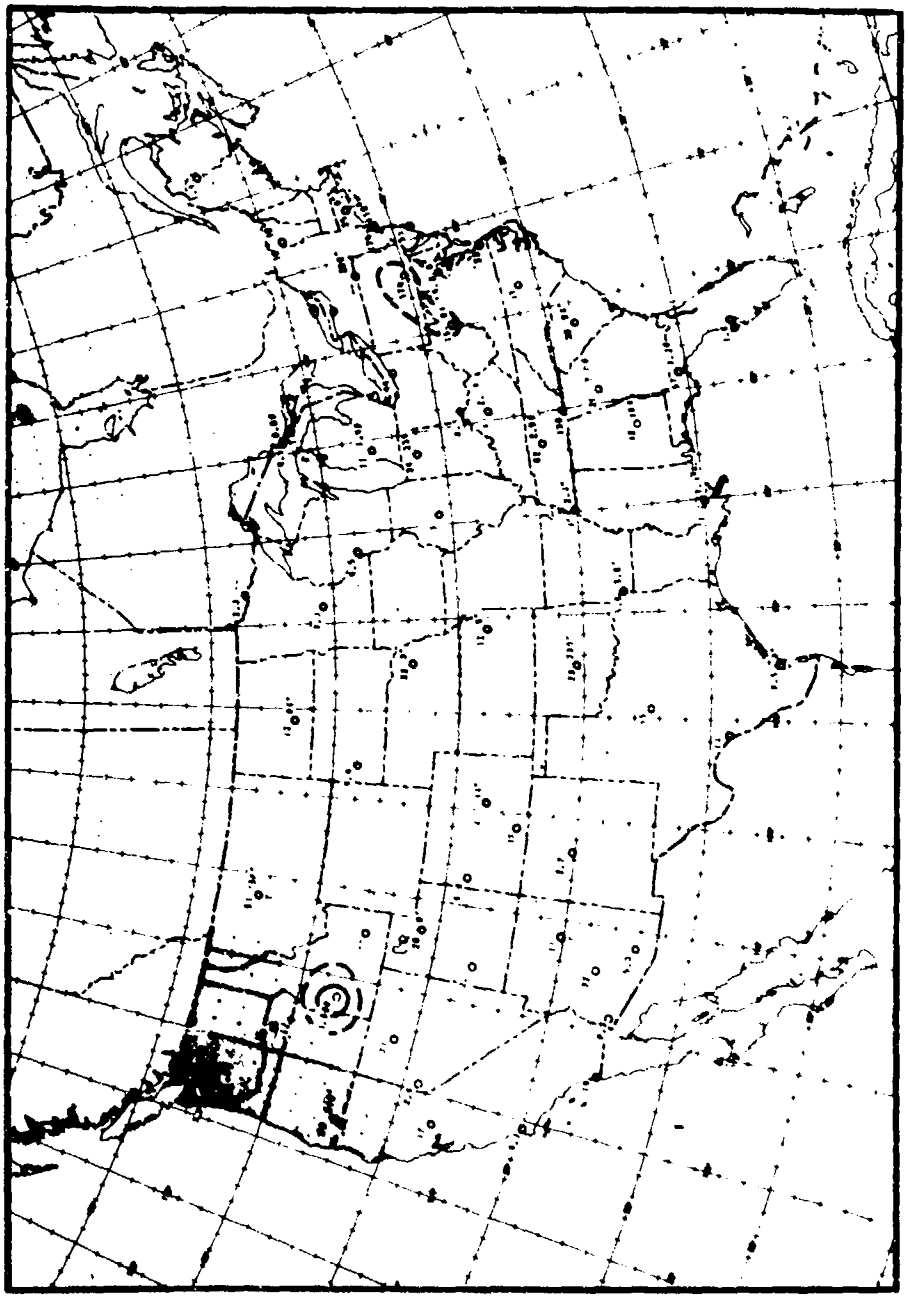


Fig. A.42 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 29 November 1951

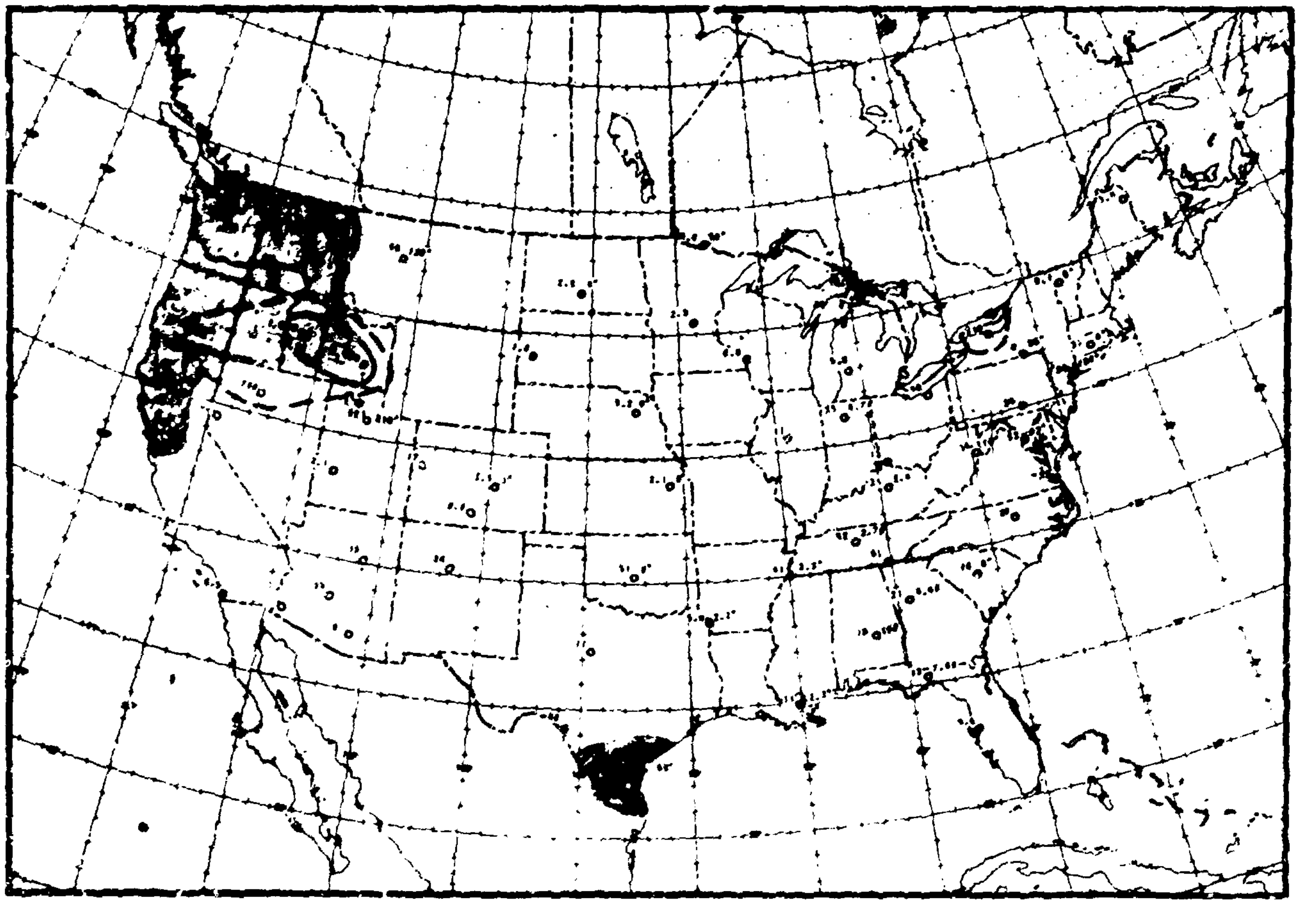


Fig. A.43 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 30 November 1951

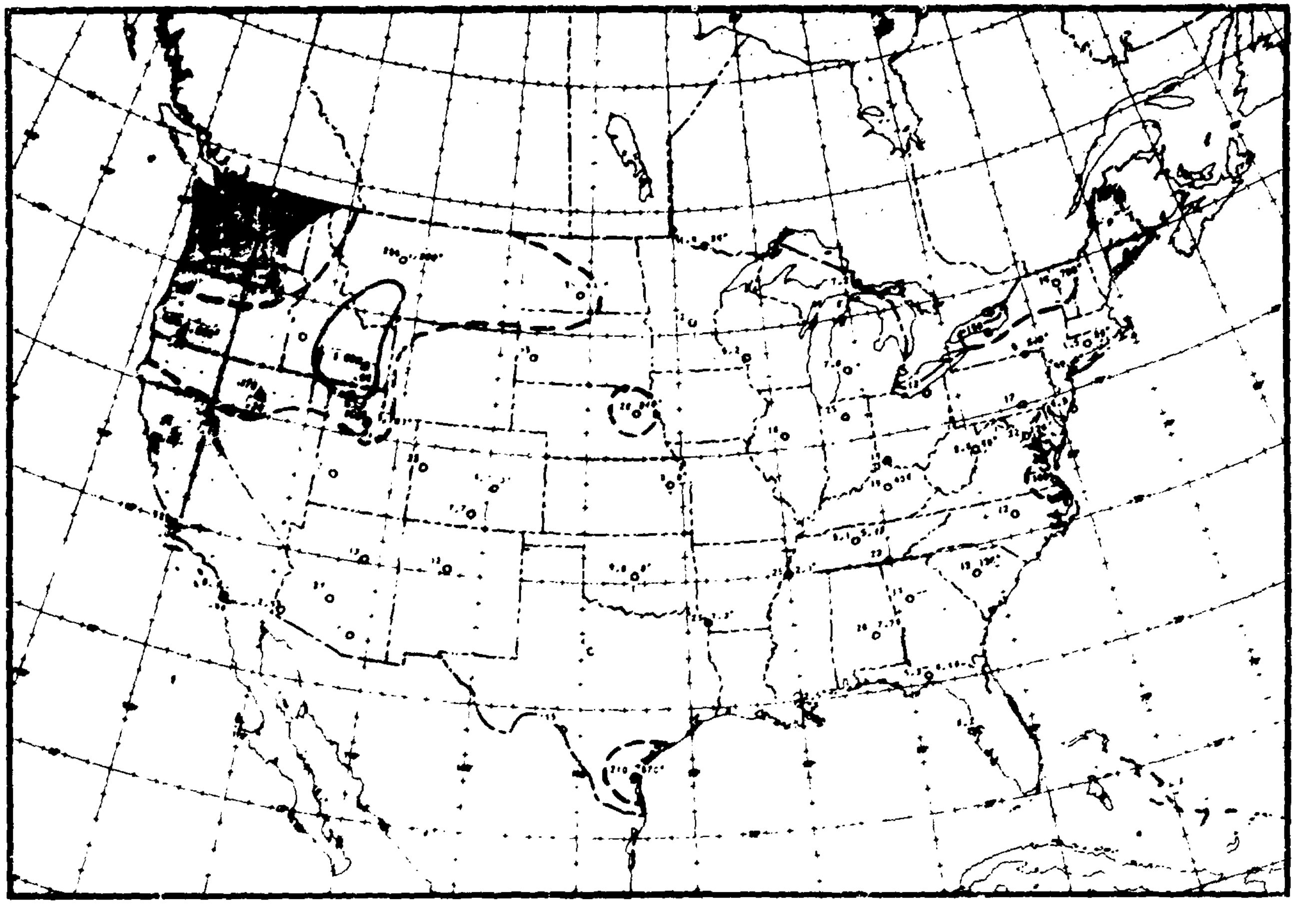


Fig. A.44 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 1 December 1951

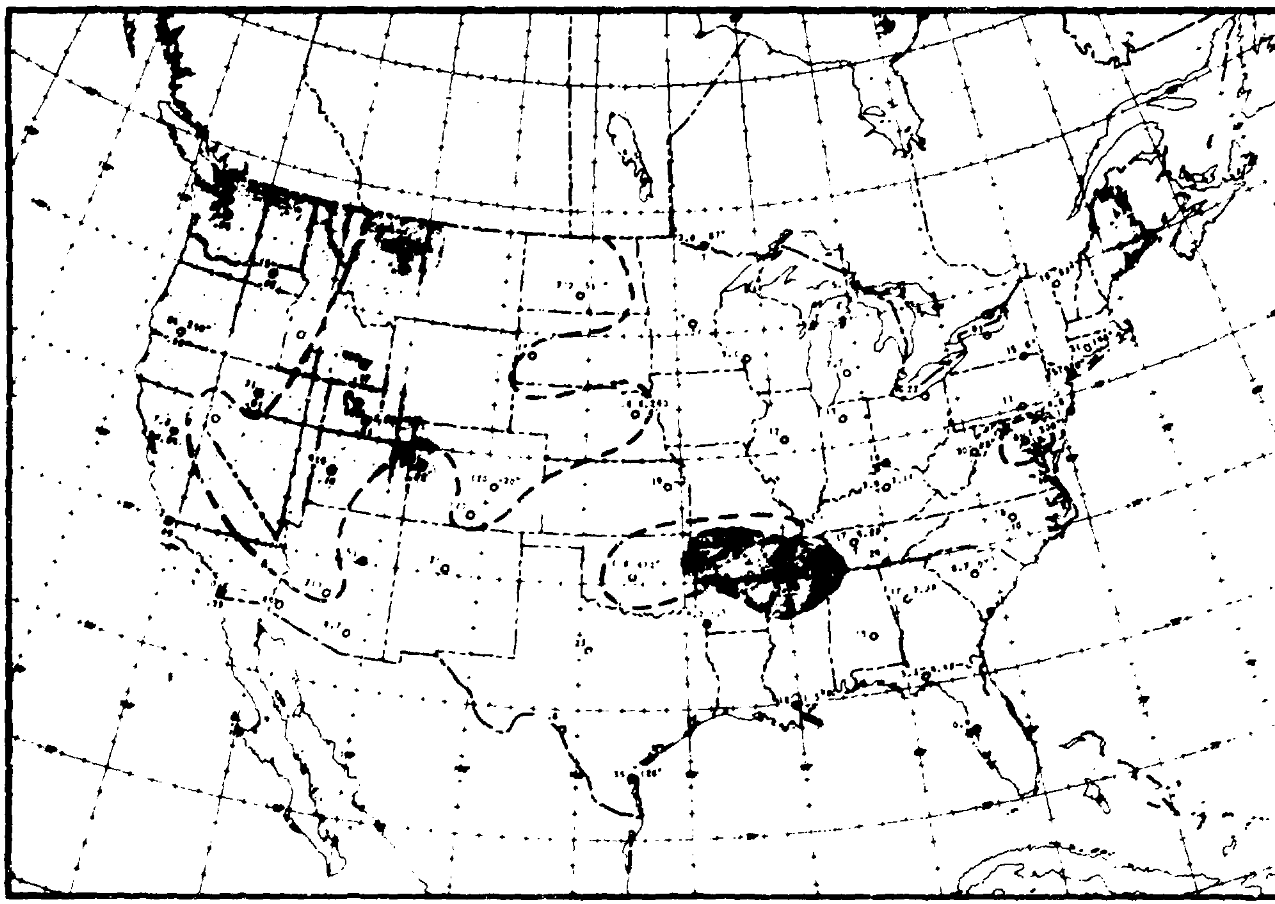


Fig. A.45 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 2 December 1951

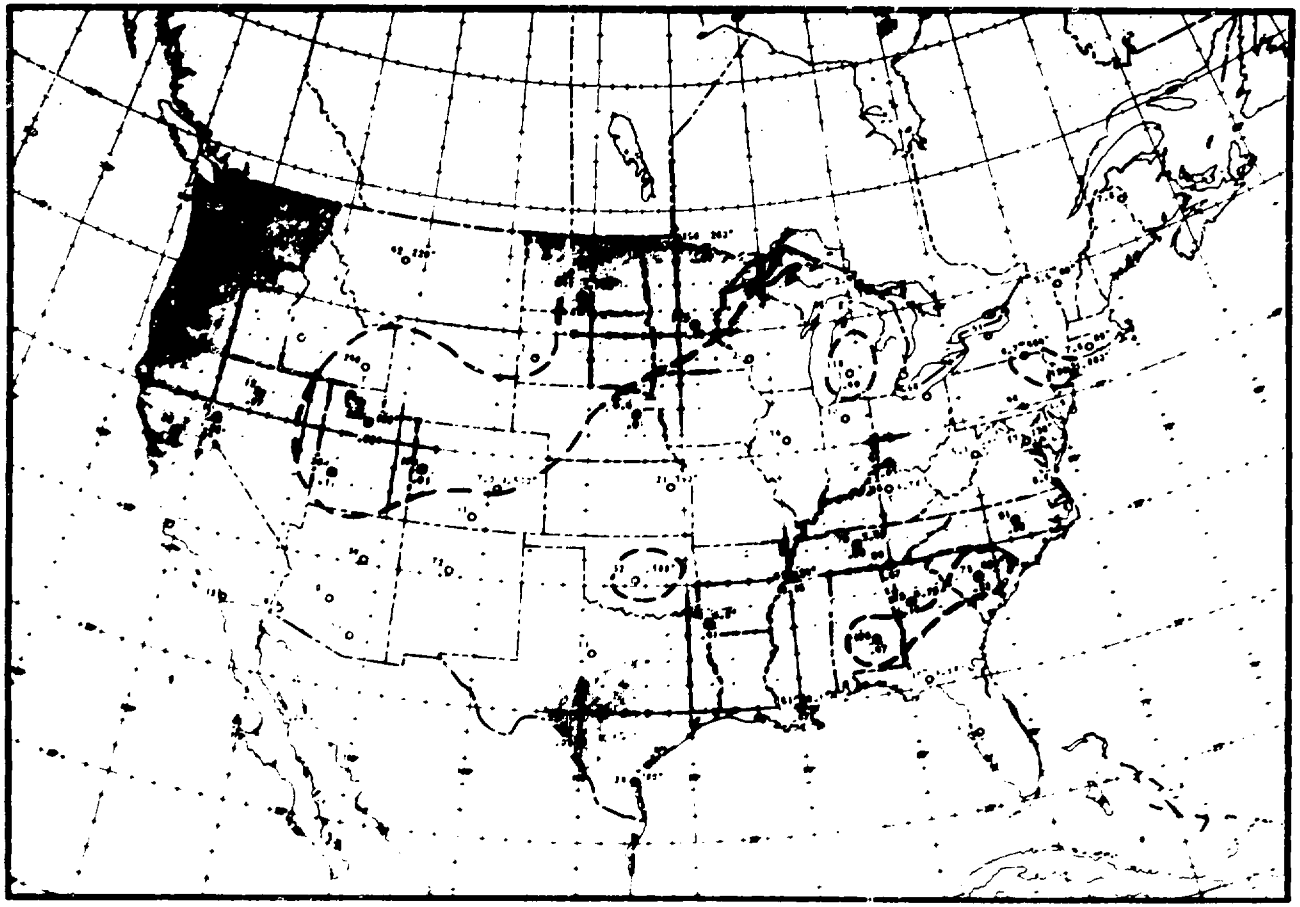


Fig. A.46 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 3 December 1951

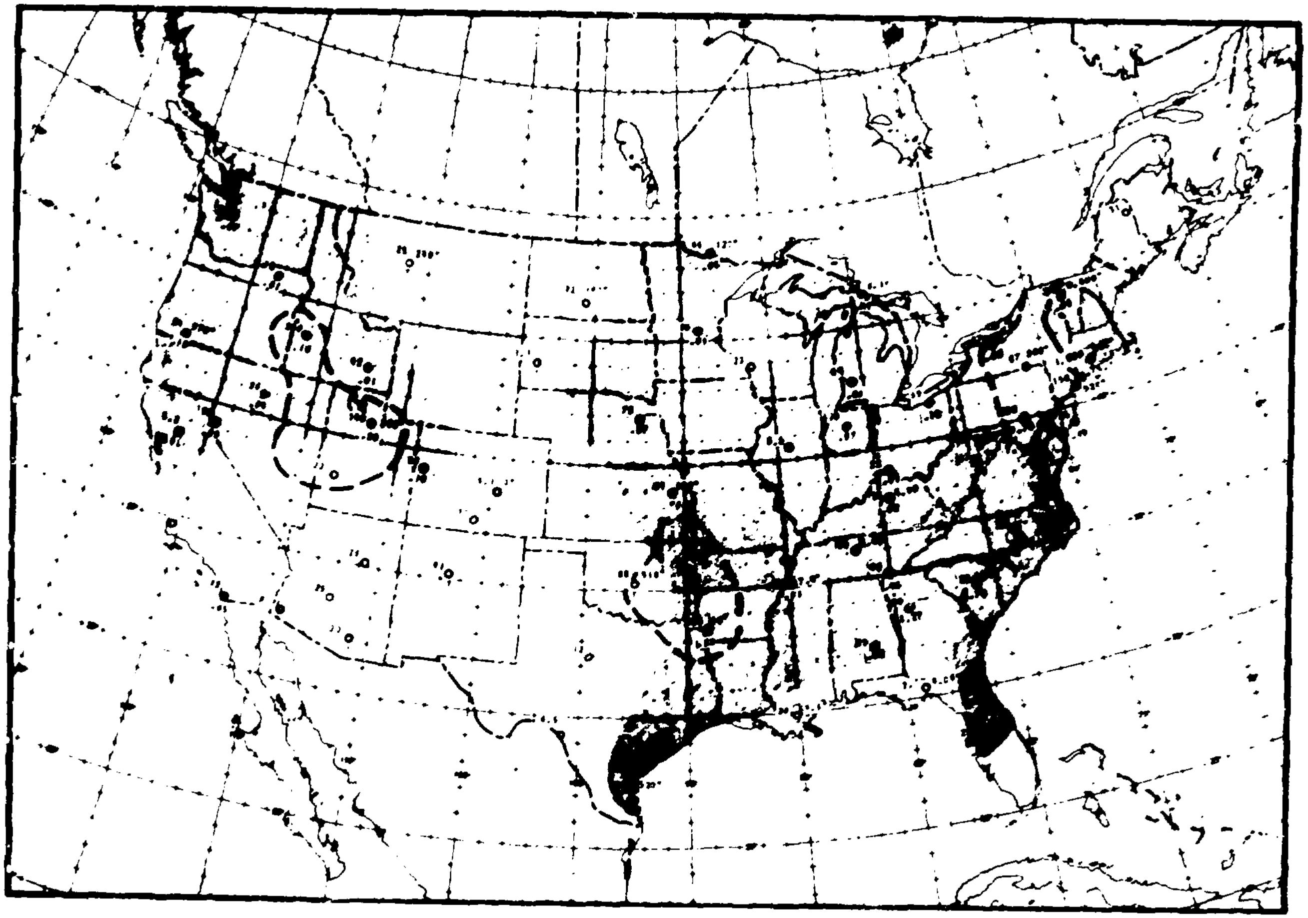


Fig. A.47 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 4 December 1952

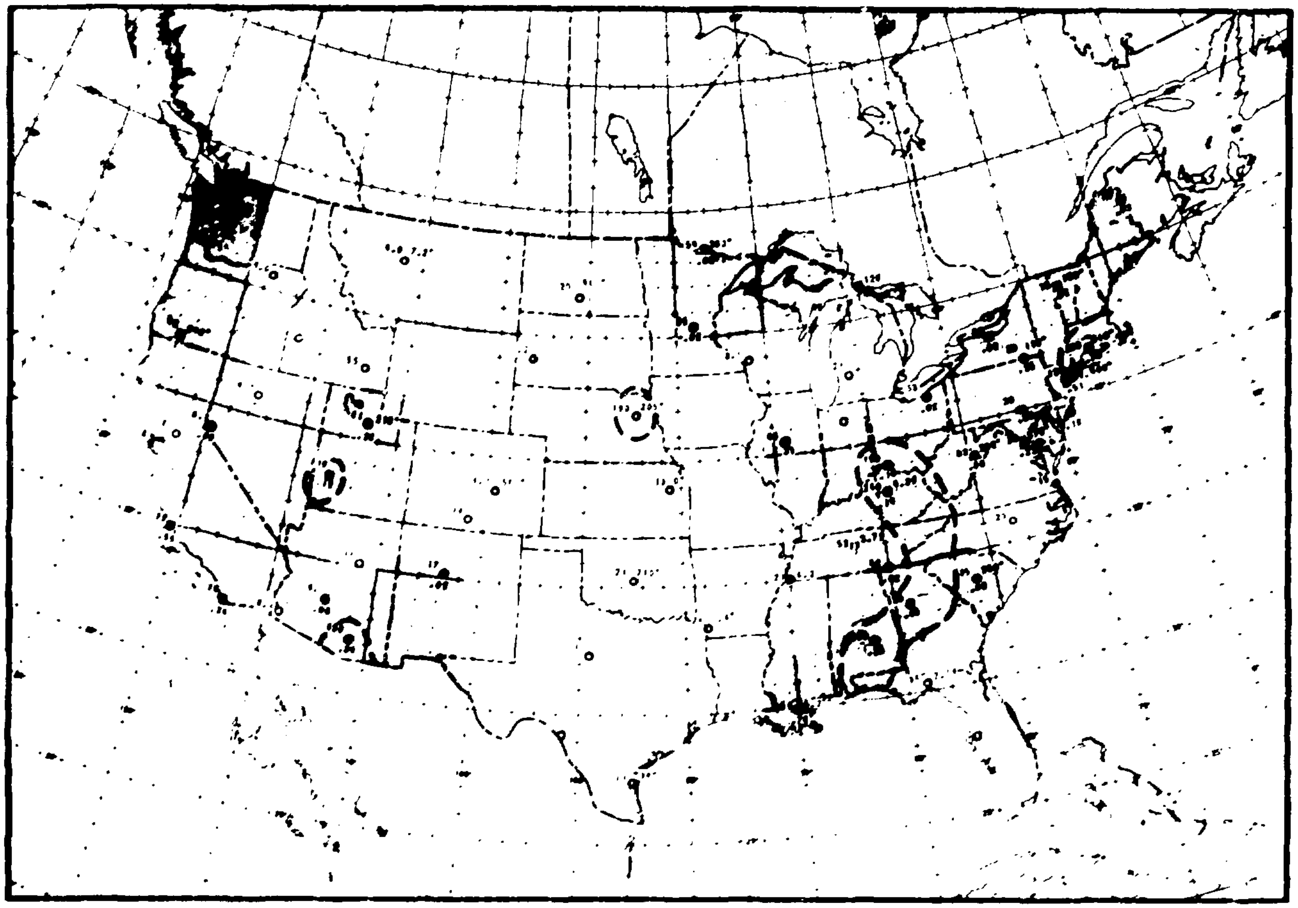


Fig. A.48 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 5 December 1951

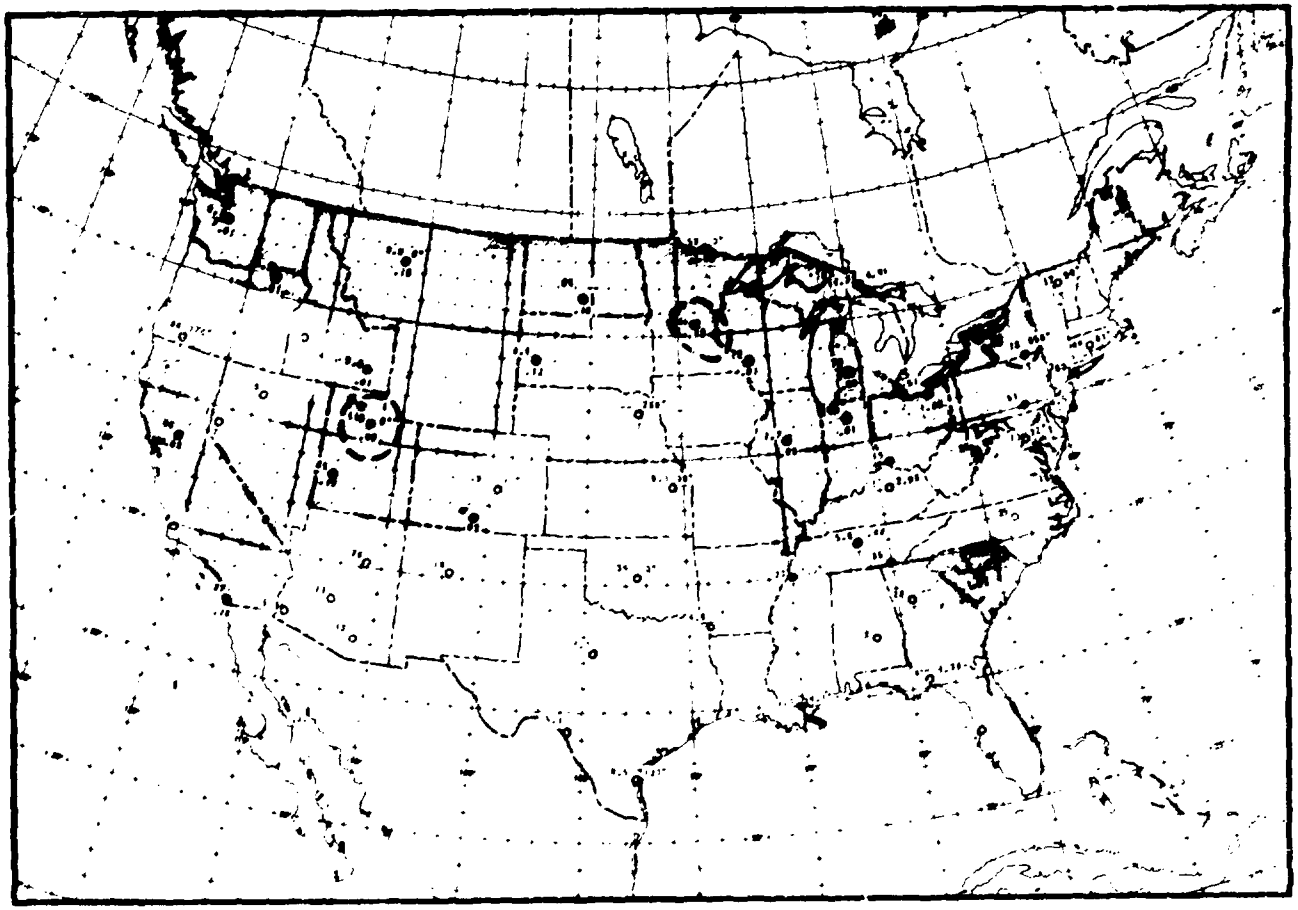


Fig. A.49 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 6 December 1951

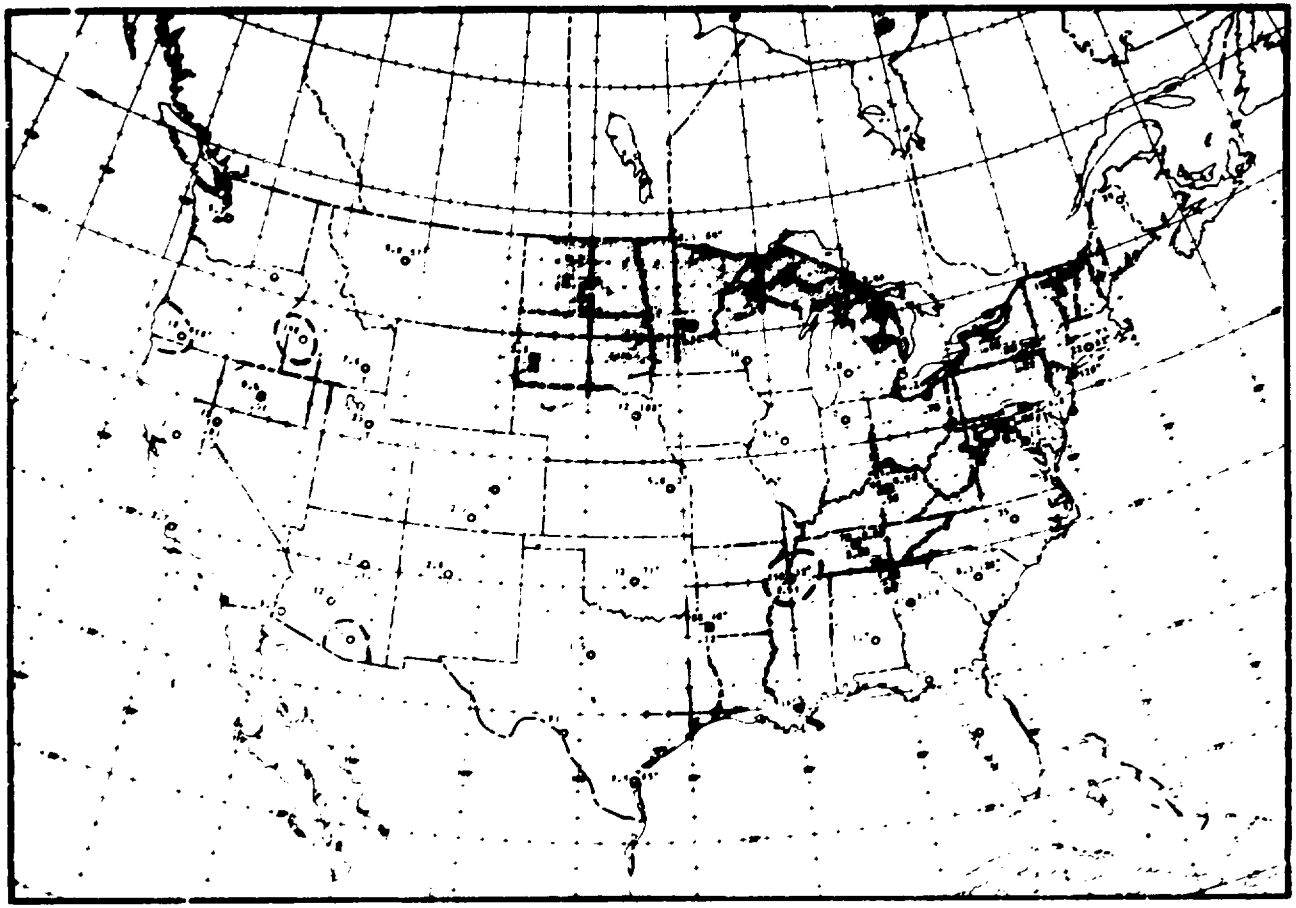


Fig. A.50 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 7 December 1951

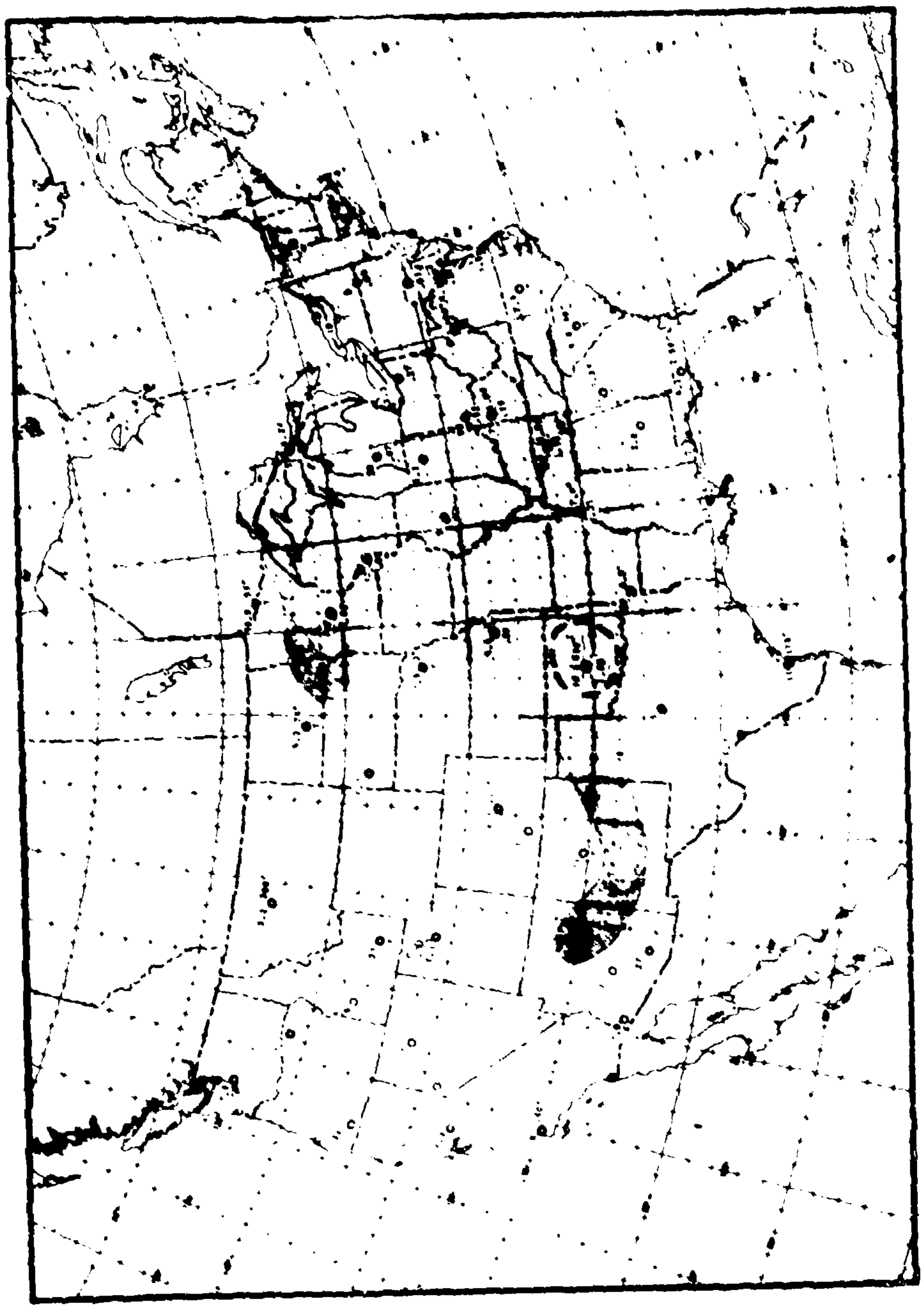


Fig. A.51 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 8 December 1951

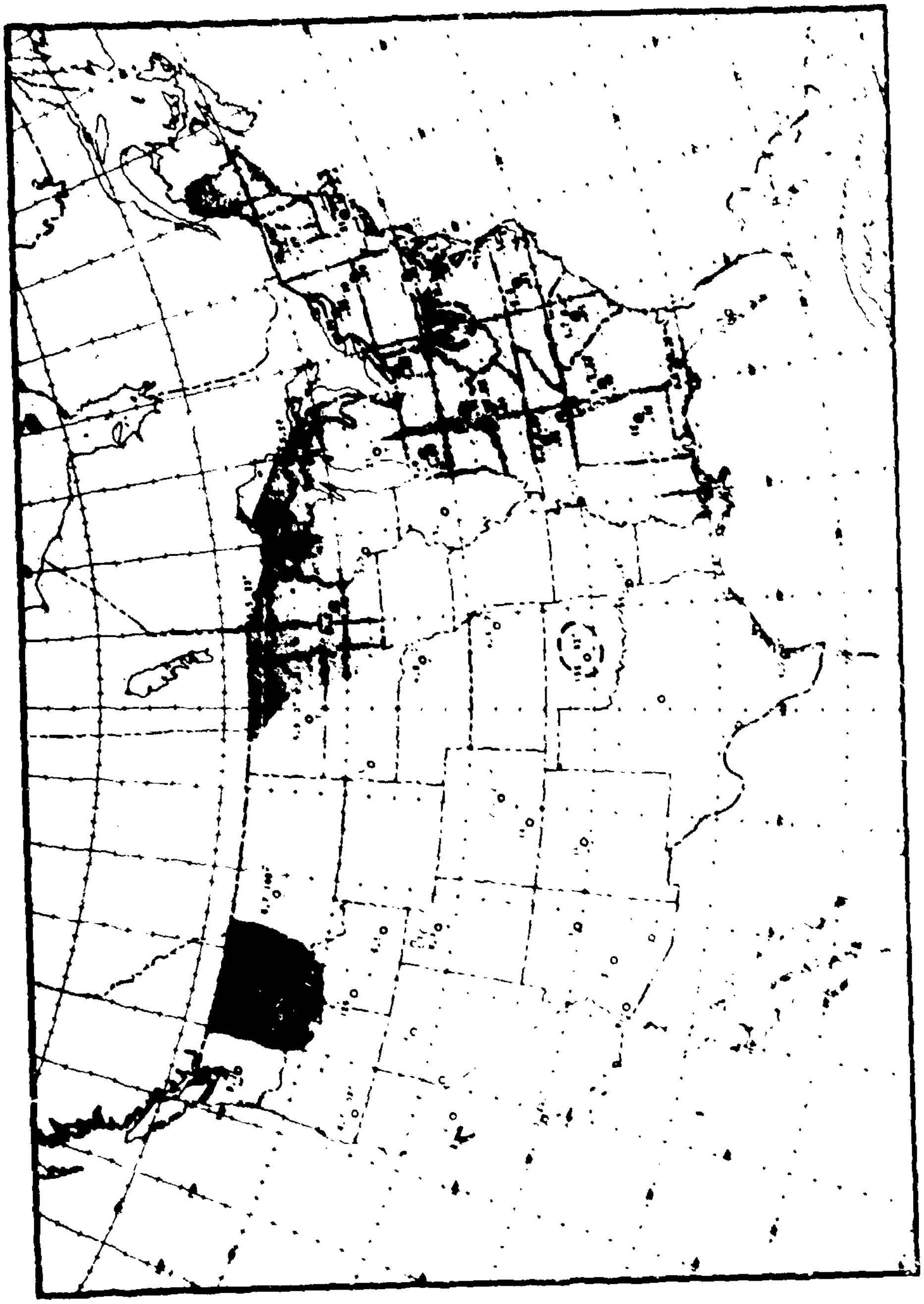


Fig. A.52 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 9 December 1951

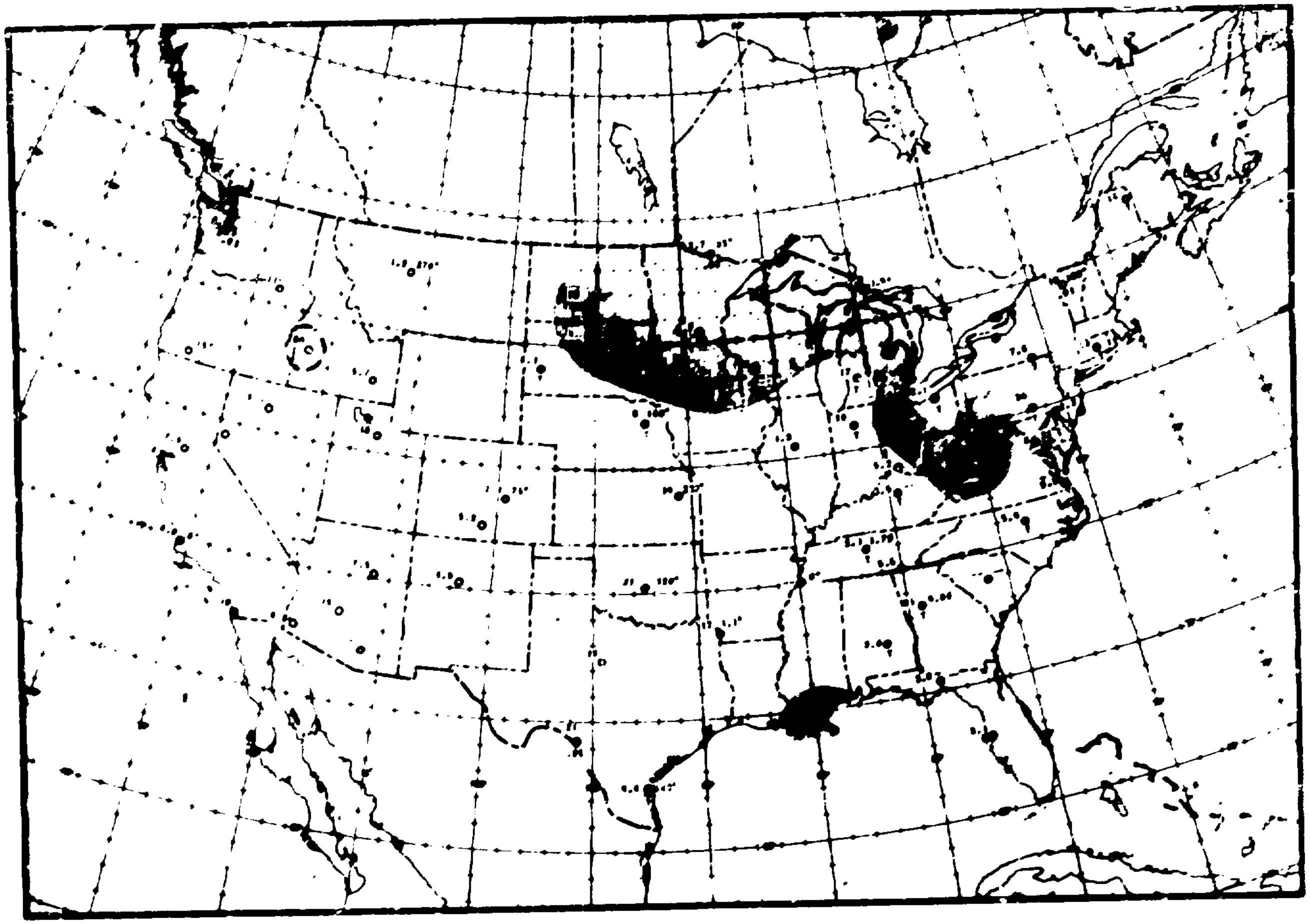


Fig. A.53 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 10 December 1951

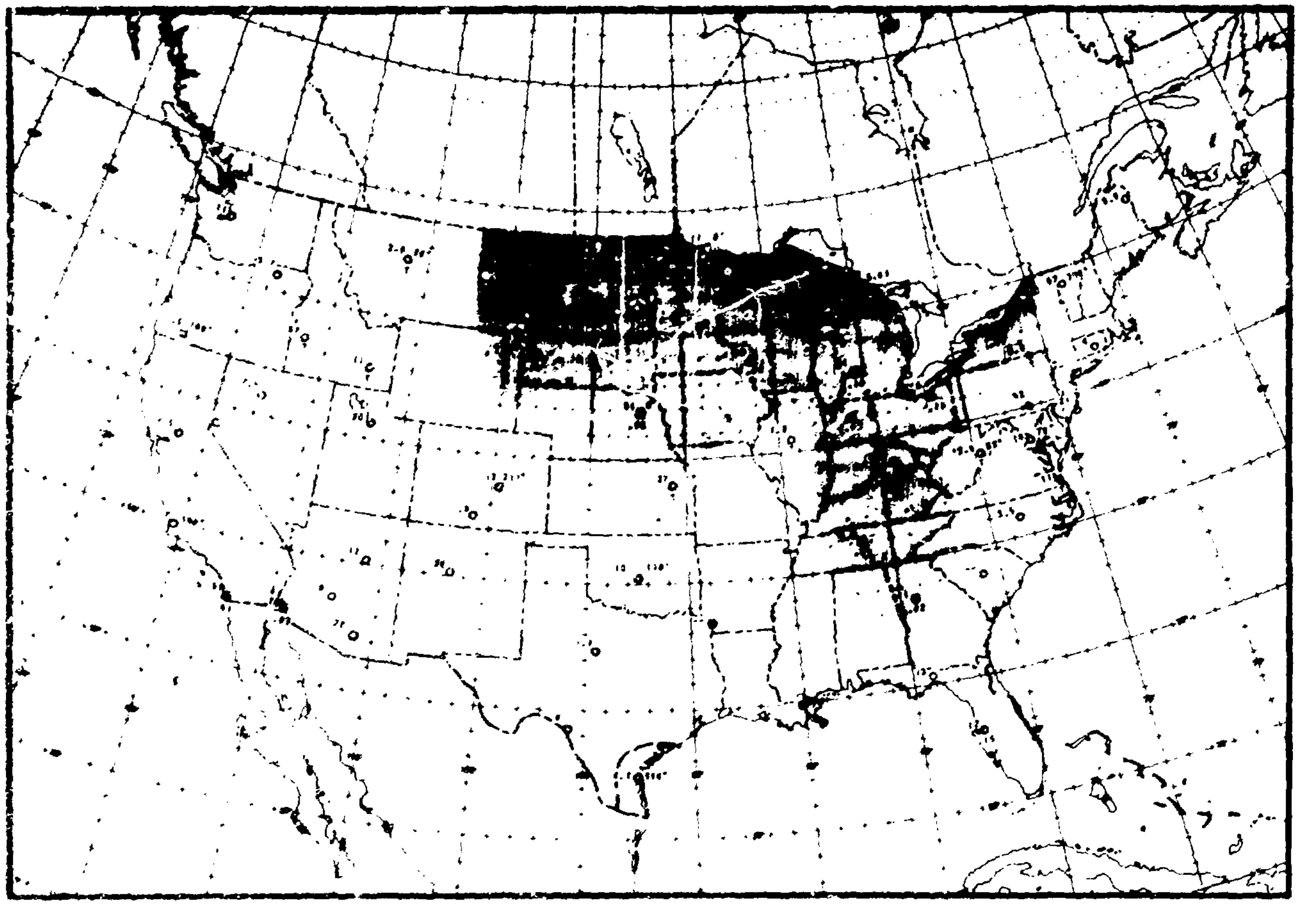


Fig. A.54 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 11 December 1951

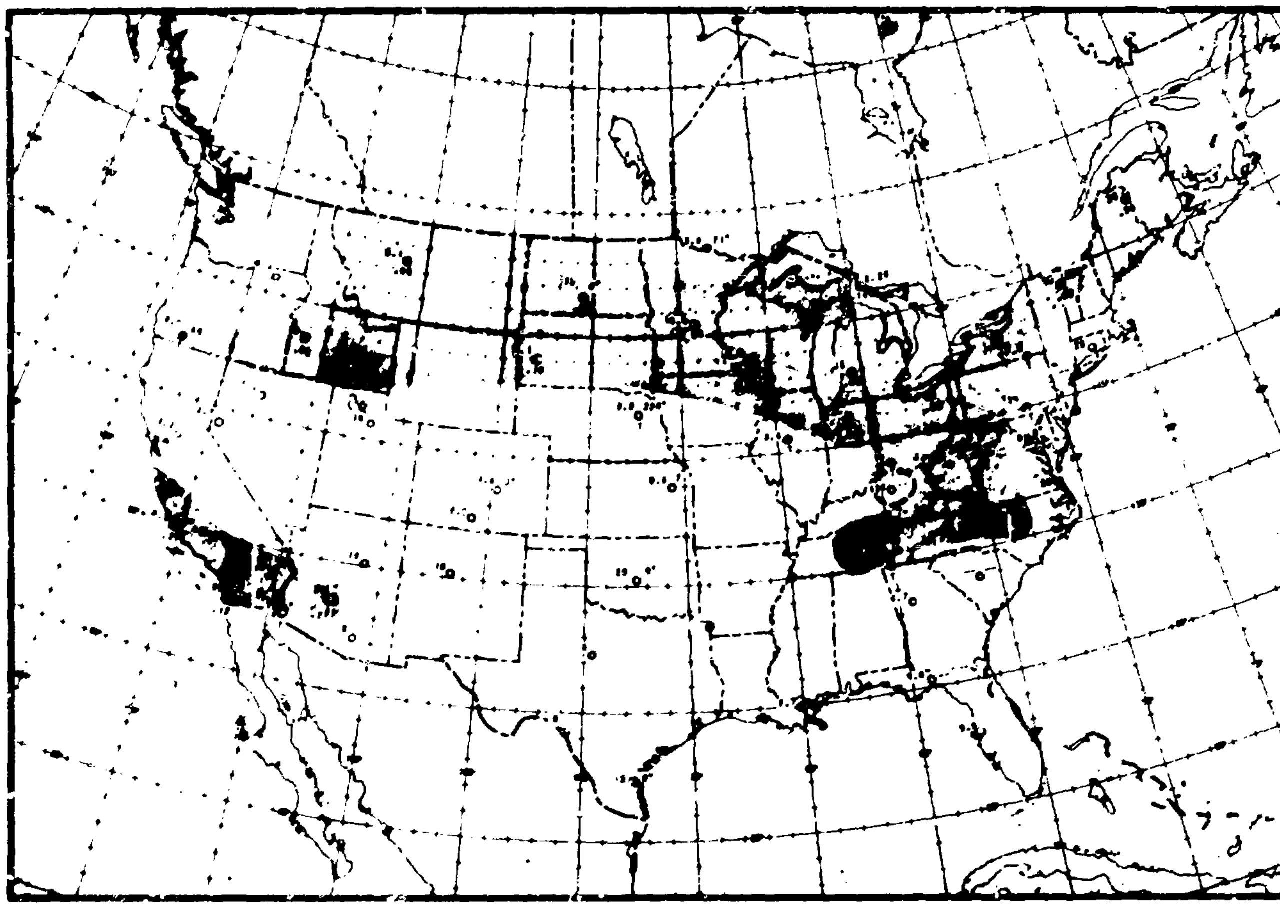


Fig. A.55 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 12 December 1951

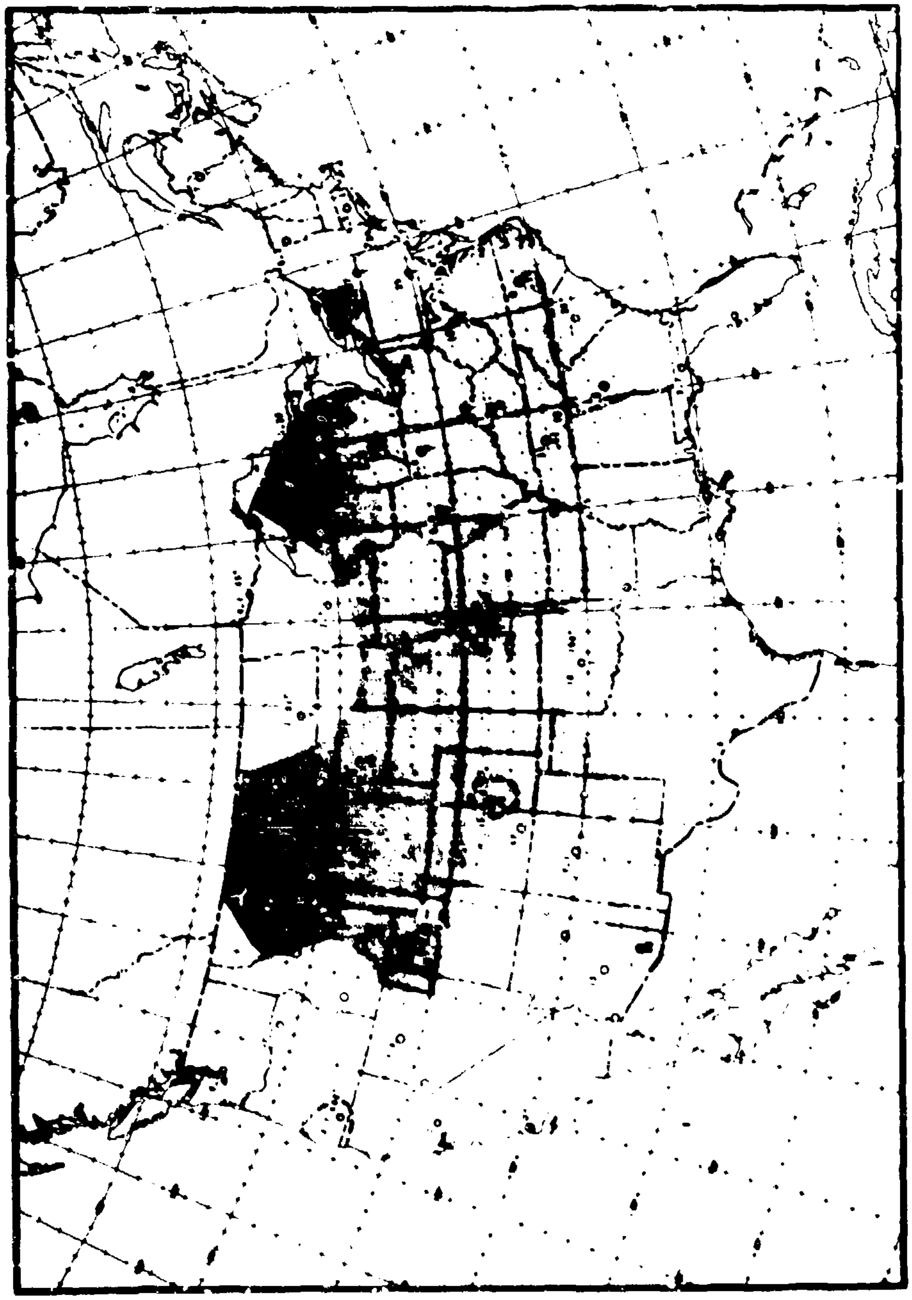


Fig. A.56 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 13 December 1951

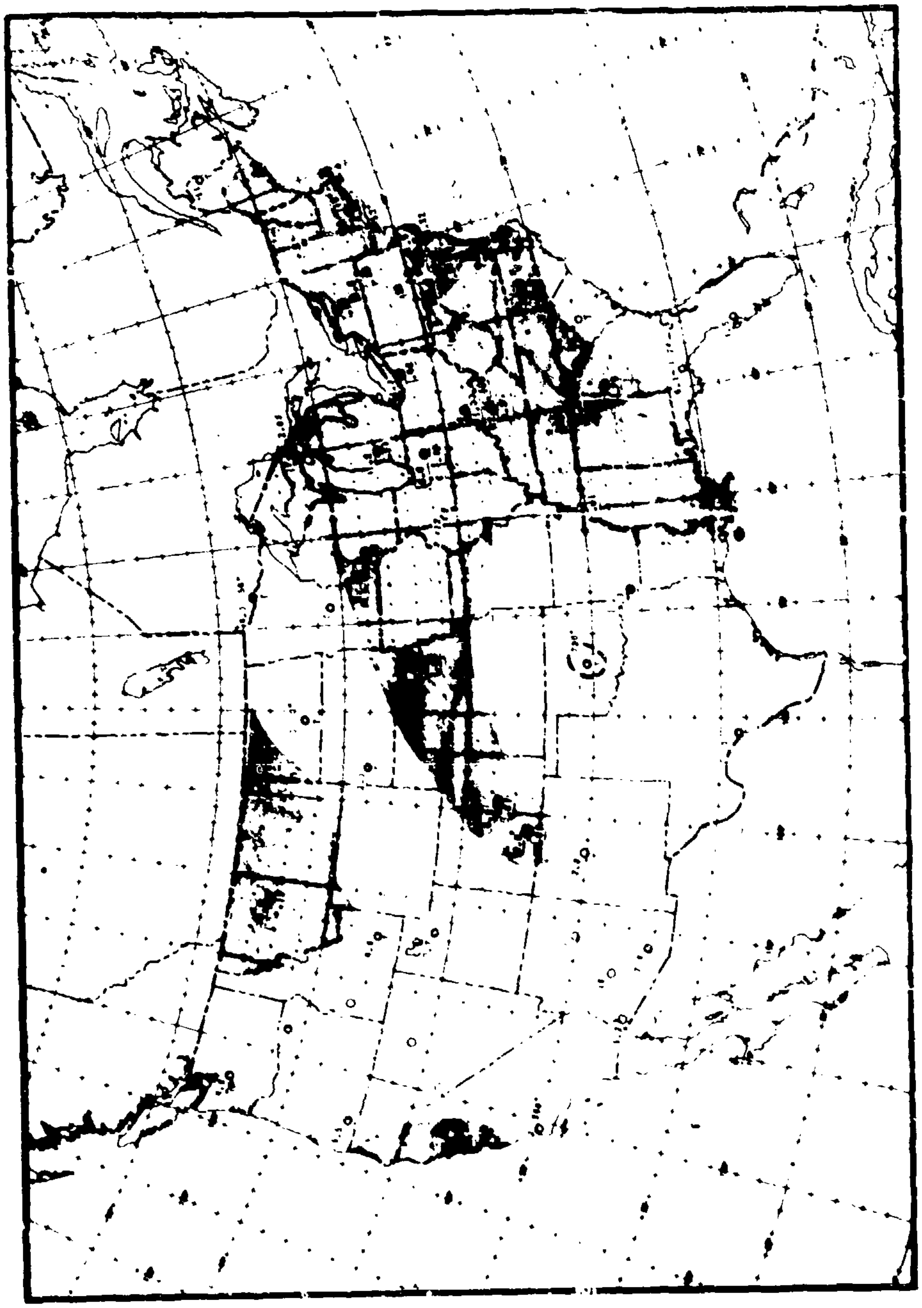


Fig. A.57 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 14 December 1951

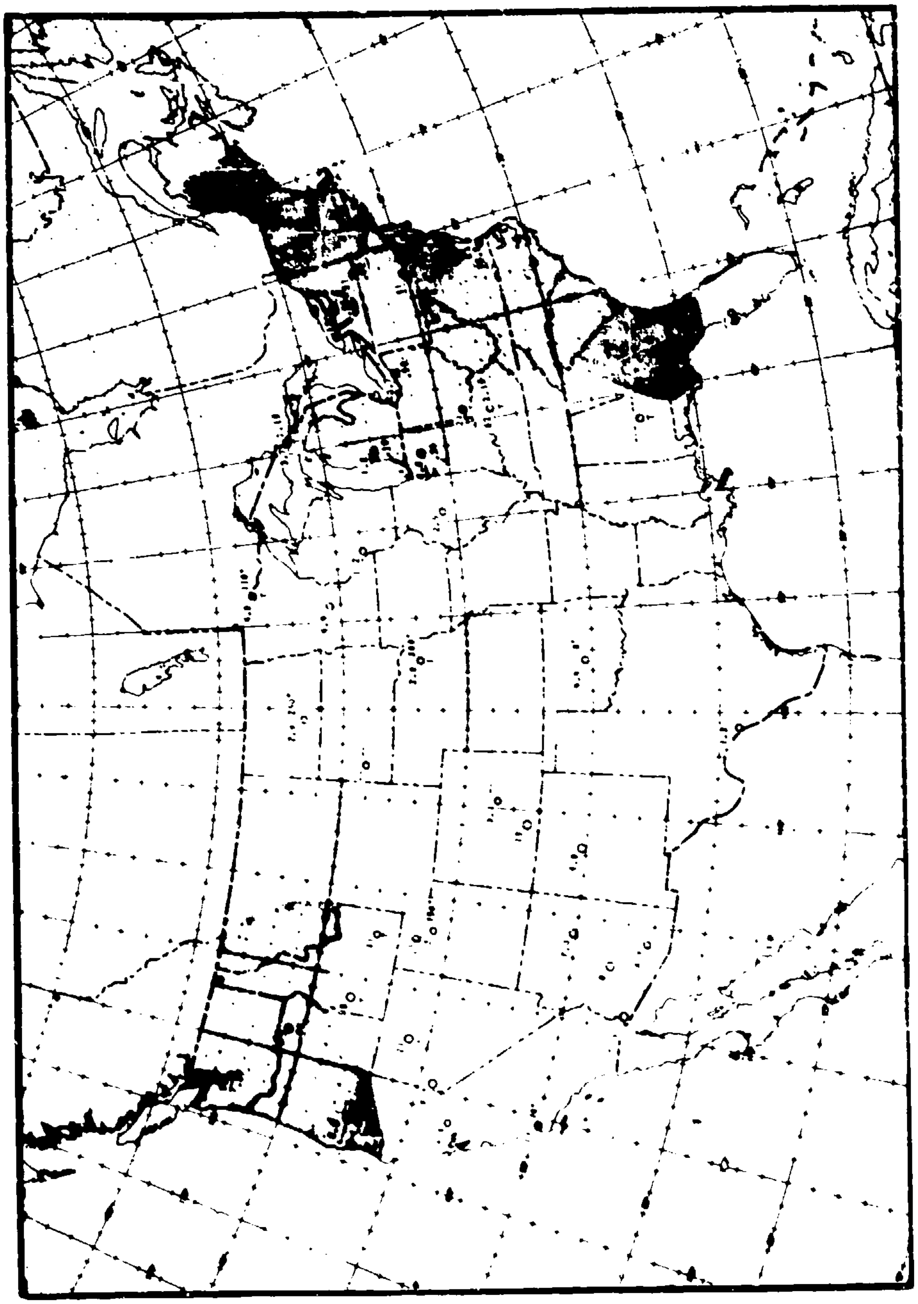


Fig. A.58 Surface Distribution of Radioactive Debris and Concurrent Precipitation, 15 December 1951

DISTRIBUTION

	Copy No.
ARMY ACTIVITIES	
Asst. Chief of Staff, G-4, Department of the Army, Washington 25, D. C. ATTN: Research and Development Division	1-2
Chief, Army Field Forces, Fort Monroe, Va.	3
Director, Operations Research Office, 6410 Connecticut Ave., Chevy Chase, Md.	4
NAVY ACTIVITIES	
Chief of Naval Operations, Department of the Navy, Washington 25, D. C. ATTN: Op-36	5
Chief, Naval Research, Department of the Navy, Washington 25, D. C.	6
Director, U. S. Naval Research Laboratory, Washington 25, D. C.	7
AIR FORCE ACTIVITIES	
Commanding General, Air Research and Development Command, P.O. Box 1395, Baltimore 3, Md.	8
Commanding General, 1009th Special Weapons Squadron, 1712 G St. NW, Washington 25, D. C.	9-65
Assistant for Atomic Energy, Headquarters, United States Air Force, Washington 25, D. C.	66
Director of Research and Development, Headquarters, United States Air Force, Washington 25, D. C.	67
AFSWP ACTIVITIES	
Chief, Armed Forces Special Weapons Project, P.O. Box 2610, Washington 13, D. C.	68-76
Commanding General, Field Command, Armed Forces Special Weapons Project, P.O. Box 5100, Albuquerque, N. Mex.	77-79
Commanding Officer, Test Command, Armed Forces Special Weapons Project, P.O. Box 5600, Albuquerque, N. Mex.	80-82
OTHER ACTIVITIES	
Weapon Test Reports Group, TIS	83
Surplus in TISOR for AFSWP	84-304

Defense Special Weapons Agency
6801 Telegraph Road
Alexandria, Virginia 22310-3398

TRC 21 August 1997

MEMORANDUM FOR DEFENSE TECHNICAL INFORMATION CENTER
ATTENTION: OMI/Mr. William Bush

SUBJECT: Declassification of AD-356275L and Withdrawal of AD-B951736

The Defense Special Weapons Agency Security Office (OPSSI) has reviewed and declassified the following report:

AD-356275L (WT-308)
Operation Buster, Nevada Proving Grounds, October - November 1951, Project 7.1, Transport of Radioactive Debris From Operations Buster and Jangle.

Distribution statement **"A"** (approved for public release) now applies.

Since AD-356275L is now declassified and approved for public release, this office requests the extracted version (AD-B951736, WT-308-EX) be destroyed because it is no longer applicable.

Completed 23 May 2000

for Naomi J. Fields
ARDITH JARRETT
Chief, Technical Resource Center

copy furn: FC/DASIAC
KSC/Alex

Completed
6 Jun 2000
B.W.